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SUMMARY OF NAVY STUDY PROGRAM FOR F4H-1 WEAPON SYSTEM

[UNCLASSIFIED TITLE]

APPENDIX TO VOLUME XI

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RADAR DIVISION

August 1960

U. S. NAVAL RESEARCH LABORATORY
Washington, D.C.

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SUMMARY OF NAVY STUDY PROGRAM FOR F4H-1 WEAPON SYSTEM

INTRODUCTION

The study effort covered by this volume is primarily concerned with the investigation of the Sparrow III 6a launching and guidance phases. From such an investigation the effect of these phases on overall system probability of success can be determined. For this reason it was necessary to conduct an accurate and detailed simulation of the Sparrow III 6a missile. Through the excellent cooperation of the prime contractor, a detailed knowledge of this missile was gained. Examples of this cooperative effort are given in references 1 and 2. After conversion of the data obtained to simulation methods and techniques, the prime contractor reviewed the entire simulation program (reference 3).

MISSILE DATA

This appendix details the basic data used in the simulation of the Sparrow III 6a missile.

Seeker Data

Figure 1 shows the 90% probability of seeker lock-on against a B-47 size target for the missile studied. This is the result of NMC tests (reference 4) scaled to the B-47 size target. It is seen that the seeker has a 90% lock-on capability against the B-47 size target, head-on, of 6.82 n. mi.

Aerodynamic Range Equations

The AN/APA-128 computer equations used in the simulation are as follows:

$$R_{max} = R_1 (h) + T_1 (V_c - V_F) \quad R_{max} \leq 6.5 \text{ n. mi.} \qquad (1)$$

R_{max} = maximum launch range

R_1 (h) varies with altitude as shown on Fig. 2

V_c = closing velocity

V_f = fighter velocity

T_1 = 11 secs for $V_c > V_f$

T_1 varies with altitude for $V_c < V_f$ as shown on Fig. 2

$$R_{min} = R_2\ (h) + T_2V_c \qquad (2)$$

R_{min} = minimum launch range

R_2 (h) varies with altitude as shown on Fig. 2

T_2 = 4.3 sec

$$R_{su} = R_{max} + T_3V_c - R_3 \qquad (3)$$

R_{su} = Pull-up range

T_3 = 10 sec

R_3 = 6000 ft

Steering Error Equations

$$V_o = 800 \left[1 + 0.41\ (1 - P/P_{SL})\right] \qquad (4)$$

$V_o = V_{ma} - V_f$

V_{ma} = average missile velocity

P = pressure at altitude

P_{SL} = pressure at sea level

$$\epsilon_a = \frac{57.3\ V_o\ \sin\lambda_a + R\ \frac{\omega k}{1+S}}{2300} \qquad (5)$$

ϵ_a = azimuth steering error in degrees

λ_a = azimuth gimbal angle

R = range in feet

ωk = azimuth line of sight rate in radian/sec

$$\epsilon_e = \frac{57.3\left[-V_o\ \sin\lambda_e\ \cos\lambda_a\right] + R\ \frac{\omega j}{1+S}}{2300} - 0.48\alpha_I \qquad (6)$$

ϵ_e = elevation steering error in degrees

λ_e = elevation gimbal angle

ω_j = elevation line of sight rate in radians/sec

α_I = angle of attack (angle between aircraft RGMA and velocity vector)

Allowable Launch Error

$$E = \lambda + K_3 \frac{R}{R_{max}} \left| V_c - K_1 V_f \right| - K_2 \left| V_c - K_1 V_f \right| \qquad (7)$$

E = allowable launch error in degrees

$\lambda = 3^{\circ}$

$K_1 = 0.75$

$K_2 = 0.0054$ deg/ft/sec

$K_3 = 0.015$ deg/ft/sec

R_{max} = maximum aerodynamic range (not limited to 6.5 n. mi.)

Missile Head Slaving

$$IEB_e = + (\lambda_e - E_e) \qquad (8)$$

$$IEB_a = + (\lambda_a - E_a) \qquad (9)$$

IEB_e = initial English Bias in elevation

IEB_a = initial English Bias in azimuth

In the F4H-1 (Sparrow III 6a) system, the missiles will be rolled 45°. The effect of this roll must be accounted for in the English Bias. Thus

$$FEB_e = 0.707\ IEB_e + 0.707\ IEB_a \qquad (10)$$

$$FEB_a = 0.707\ IEB_e + 0.707\ IEB_a \qquad (11)$$

FEB_e = final English Bias in elevation

FEB_a = final English Bias in azimuth

The initial English bias and the final English bias are then combined into a composite signal to be applied to the yaw and pitch channels of the autopilot. The equations for these composite English bias signals are:

$$-EB_p = (IEB_e - FEB_e)e^{-t} + FEB_e \tag{12}$$

$$-EB_y = (IEB_a - FEB_a)e^{-t} + FEB_a \tag{13}$$

EB_p = composite English Bias signal applied to the pitch channel

EB_y = composite English Bias signal applied to the yaw channel

Missile Head-Aim Equations

$$\lambda a_{mi} = \text{Tan}^{-1}\left\{\frac{\text{Cos } a\left[\text{Sin}\lambda_a\ (\text{Cos}\lambda_e - \dot{\lambda}_1\ \text{Sin}\lambda_e) + \dot{\lambda}_a\ \text{Cos}\lambda_a\right] + \text{Sin } a\left[\text{Sin}\lambda_e + \dot{\lambda}_1\ \text{Cos}\lambda_e\right]}{\text{Cos}\lambda_a\ (\text{Cos}\lambda_e - \dot{\lambda}_1\ \text{Sin}\lambda_e) - \dot{\lambda}_a\ \text{Sin}\lambda_a}\right\} \tag{14}$$

λa_{mi} = missile azimuth gimbal angle at launch

$\left.\begin{matrix}\dot{\lambda}1 = \omega j \\ \dot{\lambda}2 = \omega_k\end{matrix}\right\}$ filtered with $\frac{1}{1+S}$ type filter

a = stored missile roll angle with respect to the interceptor

$$\lambda e_{mi} = \text{Tan}^{-1}\left\{\frac{\text{Cos}\lambda a_{mi}\left\{\text{Cos } a(\text{Sin}\lambda_e + \dot{\lambda}_1\ \text{Cos}\lambda_e) - \text{Sin } a\left[\text{Sin}\lambda_a\ (\text{Cos}\lambda_e - \dot{\lambda}1\ \text{Sin}\lambda_e) + \dot{\lambda}_2\ \text{Cos}\lambda_a)\right]\right\}}{\text{Cos}\lambda_a(\text{Cos}\lambda_e - \dot{\lambda}_1\ \text{Sin}\lambda_e) - \dot{\lambda}_2\ \text{Sin}\lambda_a}\right\} \tag{15}$$

λe_{mi} = missile elevation gimbal angle at launch

Sequence of Launch Operations

There are several time delays between missile commitment and seeker lock-on time. It is important to inject these time delays into the over-all simulation. The sequence of events occurring at launch are:

1. Missile commitment — zero time

2. From missile commitment to start of ejection stroke (Umbilical is pulled at start of ejection stroke) — 1.01 seconds

3.	Motor ignition	1.08 seconds
4.	End of stroke	1.09 seconds
5.	Thrust applied	1.23 seconds
6.	Wing unlock	1.41 seconds
7.	End of thrust	3.23 seconds
8.	Seeker lock-on	2.32 seconds for R_{min} launch 3.23 seconds for R_{max} launch

Noise Effects

There are several noise effects which must be considered in the simulation of the launching and guiding of the Sparrow III missile. The first of these is the noise due to radome refraction in the Sparrow III seeker. The radome refraction curve used was obtained from Raytheon and is shown by Fig. 3.

The next noise effect which was considered is that due to the target. The noise power density versus range for the Sparrow III missile against a B-47 size target is shown on Fig. 4 (reference 5).

The final noise effect that was simulated is that due to transients occurring during missile launch. These transients are due to the fact that the missile is launched into a high velocity airstream. The resulting transient effects are given by Figs. 5a thru 8b. This data was obtained from McDonnell Aircraft Co. (reference 6).

Seeker and Autopilot Loops

The block diagrams of the seeker and autopilot are shown by Fig.9. The gains and the time constants are given on Table I. The definitions of the additional symbols used are as follows:

ω_{J_m} = antenna elevation angular rate with respect to inertial space

ω_{K_m} = antenna azimuth angular rate with respect to inertial space

$n_{c(p)}$ = normal acceleration commanded in pitch

$n_{c(y)}$ = normal acceleration commanded in yaw

n_z = normal acceleration measured along the missile Z' axis

n_y = normal acceleration measured along the missile Y' axis

p, q, r = components of missile angular velocity about the body axes x, y' and z' respectively

K = autopilot gain

τ = autopilot time constant

δ_p = angular deflection of pitch wings

δ_y = angular deflection of yaw wings

δ_a = differential angular deflection of pitch wings

$\overline{R}$ = Range

$\dot{R}_{FT}$ = range rate, fighter-to-target

$\dot{R}_{FM}$ = range rate, fighter-to-missile

$\dot{R}_{MT}$ = range rate, missile-to-target

IC = initial conditions

Aerodynamic Data

The orientations of various angles and coefficients pertaining to the aerodynamic data are shown on Fig. 10. The actual aerodynamic data (reference 7) used in the simulator are shown on Fig. 11 thru 67. A brief description of each type of data along with the appropriate figure numbers are as follows:

1. C_{D_O} = Zero-lift drag coefficient - C_{D_O} for all altitudes is given for the boost and the glide conditions as a function of Mach in Fig. 11. The change in coefficient of drag due to normal force is given by Figs. 12 and 13.

2. C_N = Coefficient of normal force C_N, corrected for aeroelastic effects, is given as a function of Mach, wing deflection, angle of attack and roll angle on Figs. 14 thru 31.

3. C_m = Pitching moment coefficient C_m, corrected for aeroelastic effects, is given as a function of Mach, wing deflection, angle of attack and roll angle on Figs. 32 thru 49.

4. $C_{m_{\dot{\delta}}}$ & $C_{m_{\dot{\alpha}}}$ = Estimated pitch derivatives $C_{m_{\dot{\delta}}}$ and $C_{m_{\dot{\alpha}}}$ are given on Figs. 50 and 51.

5. C_{ℓ} = Estimated roll moment coefficient C_{ℓ} is given as a function of Mach, angle of attack and roll angle for differential wing deflection of 6° on Figs. 52 thru 62. For angle of attack and wing deflection both equal to zero, the roll moment coefficient $C_{\ell_{\delta_a}}$ is given on Fig. 63 as a function of Mach. Roll moment coefficient versus angle of attack for $\delta_a = 0^{\circ}$ is not currently available and will be assumed to be zero.

6. C_{ℓ_p} = Estimated roll clamping moment coefficient. C_{ℓ_p} is given as a function of Mach number on Fig. 64.

7. Aeroelastic correction factors are given for the wings, tail and aerodynamic center on Figs. 65, 66, 67.

8. The thrust vs time curves of Fig. 68 were approximated by assuming a thrust (at sea level) of 7300 lbs. acting for an interval of two seconds. The thrust correction for altitude is obtained from Fig. 69.

Missile Physical Characteristics

These characteristics are for the C8 motor without short autopilot.

Weight before launch = 399.8 lbs.

Weight after burnout = 328.8 lbs.

Center of gravity before launch = Sta. 82.01" + 0.5" - 1.0"

Center of gravity after burnout = Sta. 75.01" + 0.5" - 1.0"

Wing area (S) = 1.265 ft^2 per panel - 2.53 ft^2 total

Tail area = 0.77 ft^2 each panel

Wing span $(\bar{b})$ = 3.3 ft

Wing chord $(\bar{c})$ = 1.106 ft

Mechanical wing limits = $\pm 22^\circ$

Electrical wing limits = $\pm 20^\circ$

Antenna mechanical gimbal limits = $\pm 50^\circ$

Antenna electrical gimbal limits = $\pm 46^\circ$

Moment of Inertial:

I_{xx} = 1.45 slug-ft^2 at launch, 1.31 slug-ft^2 at burnout

I_{yy} = 103 slug-ft^2 at launch, 79.7 slug-ft^2 at burnout

I_{zz} = 103 slug-ft^2 at launch, 79.9 slug-ft^2 at burnout

TABLE I

SPARROW III AUTOPILOT PARAMETERS

$t \triangleq$ TIME FROM LAUNCH (TIME FROM END OF STROKE)

$t_1 \triangleq$ UNLOCK TIME = (0.4-0.08) SEC

$t_2 \triangleq$ END-OF-BOOST TIME = (2.22-0.08) SEC

$t_3 \triangleq$ MISSILE SEEKER LOCK-ON TIME = (2.22-0.08) SEC

ALTITUDE CONDITION	A	B	C	D
ALTITUDE	SL-17K	17-32K	32-46	>46K
τ_s (SEC)	.15 0.085	.15 0.085	0.4 0.129	0.4 0.129
τ_5 YAW (SEC) PITCH	4.93 3.87	3.17 2.49	1.70 1.33	1.09 .857
K_5 (o/g SEC)	3.57	5.56	10.5	16.3
τ_β (SEC)	0.0053	0.0063	0.008	0.008
G_2 (o/o/SEC)	$\frac{1.14}{1+25S}$	$\frac{1.14}{1+12.5S}$	$\frac{3.43}{1+25S}$	$\frac{3.43}{1+12.5S}$
K_8 o/o/SEC.	0.054	0.110	0.21	0.43

ACKNOWLEDGEMENTS

The data presented in this report is that collected and used in the missile simulation phase of the Navy's Air-to-Air Missile Study Program. It was supplied to NRL directly by the Raytheon Company from personnel at the Bedford Laboratory who also checked the manner in which it was used in the simulation on the IBM 704 computer. The Technical Directors (NRL) of the study program wish to thank the personnel of the Bedford Laboratory for their assistance in this vital phase of the Navy's effort. Computer services and the bulk of work necessary to convert the raw data into a well coordinated simulation of the missile was performed by the Analytical Section of the Westinghouse Air Arm Division. The Technical Directors would also like to thank these people for the role they played in obtaining meaningful results for the Navy's arsenal of knowledge.

This report was prepared by the following members of the Systems Section, Equipment Research Branch.

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6. MAC Missile Transient Data.

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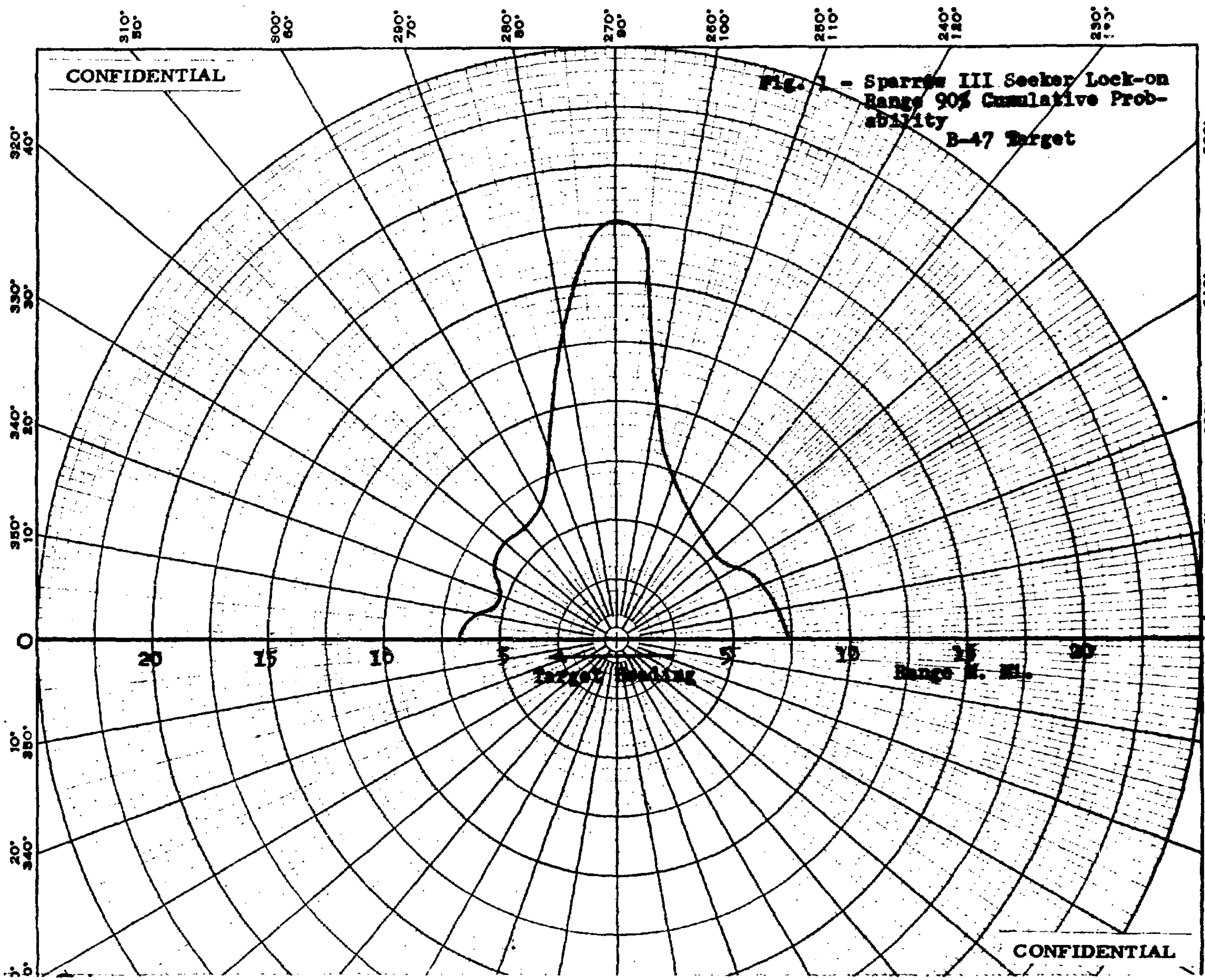

Fig. 1 - Sparrow III Seeker Lock-on Range 90% Cumulative Probability
B-47 Target

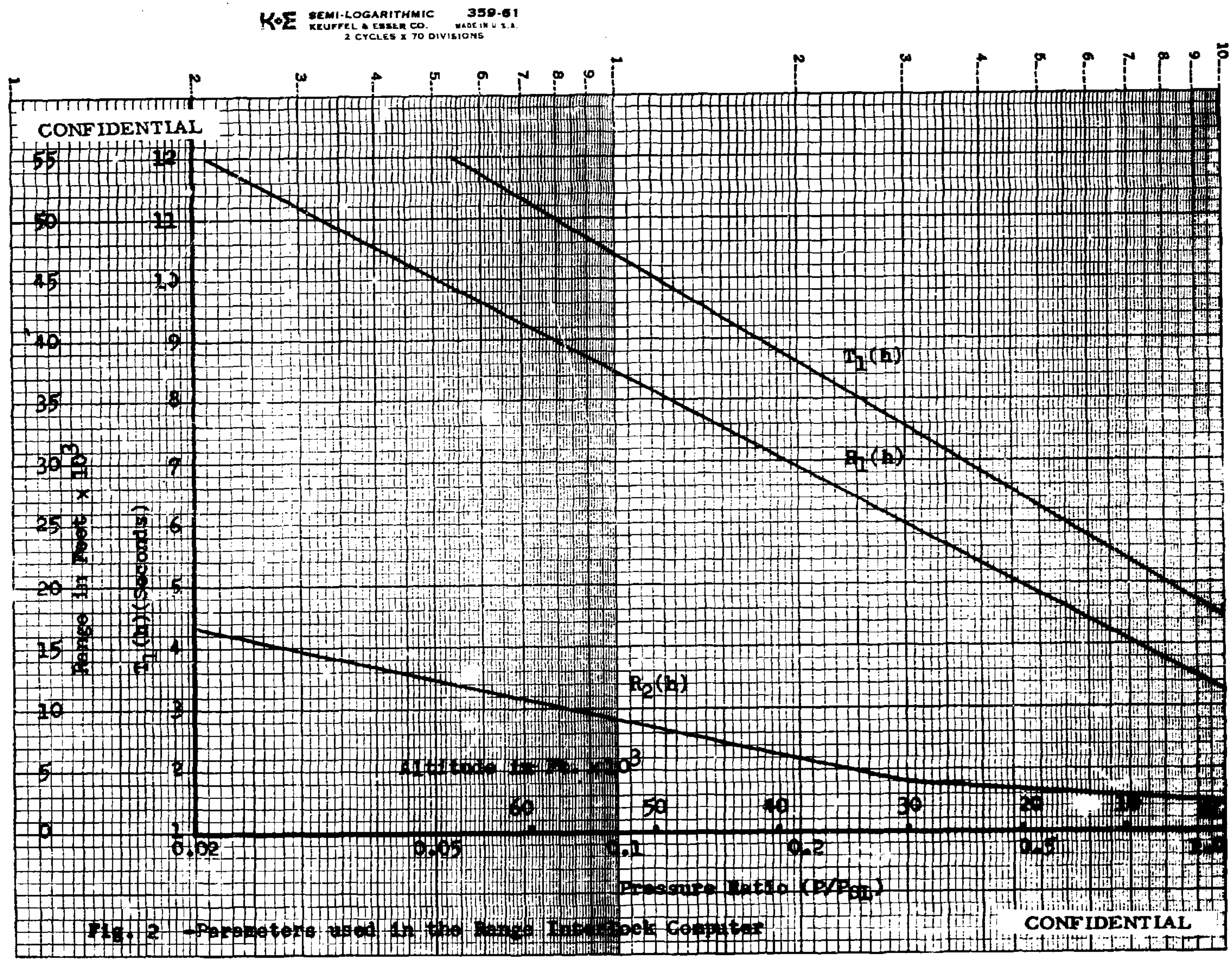

Fig. 2 -Parameters used in the Range Interlock Computer

Fig. 3 - Sparrow III Radome Refraction Curve

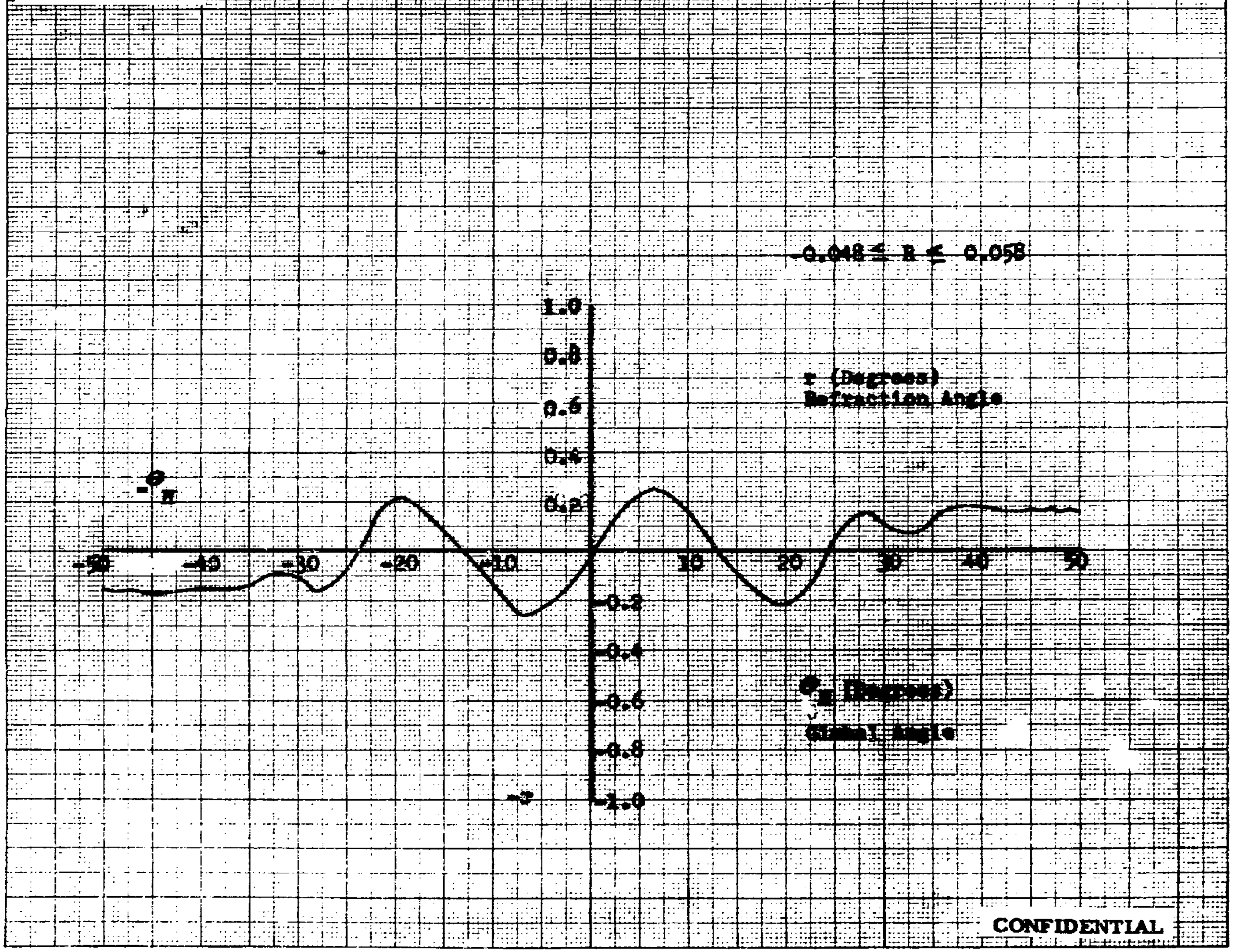

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Fig. 4 - Noise Power Density vs Range - B-47 Target Nose View. Data Computed for Sparrow III Assuming 14 Deg. Beamwidth and 285 cps Lobing Rate.

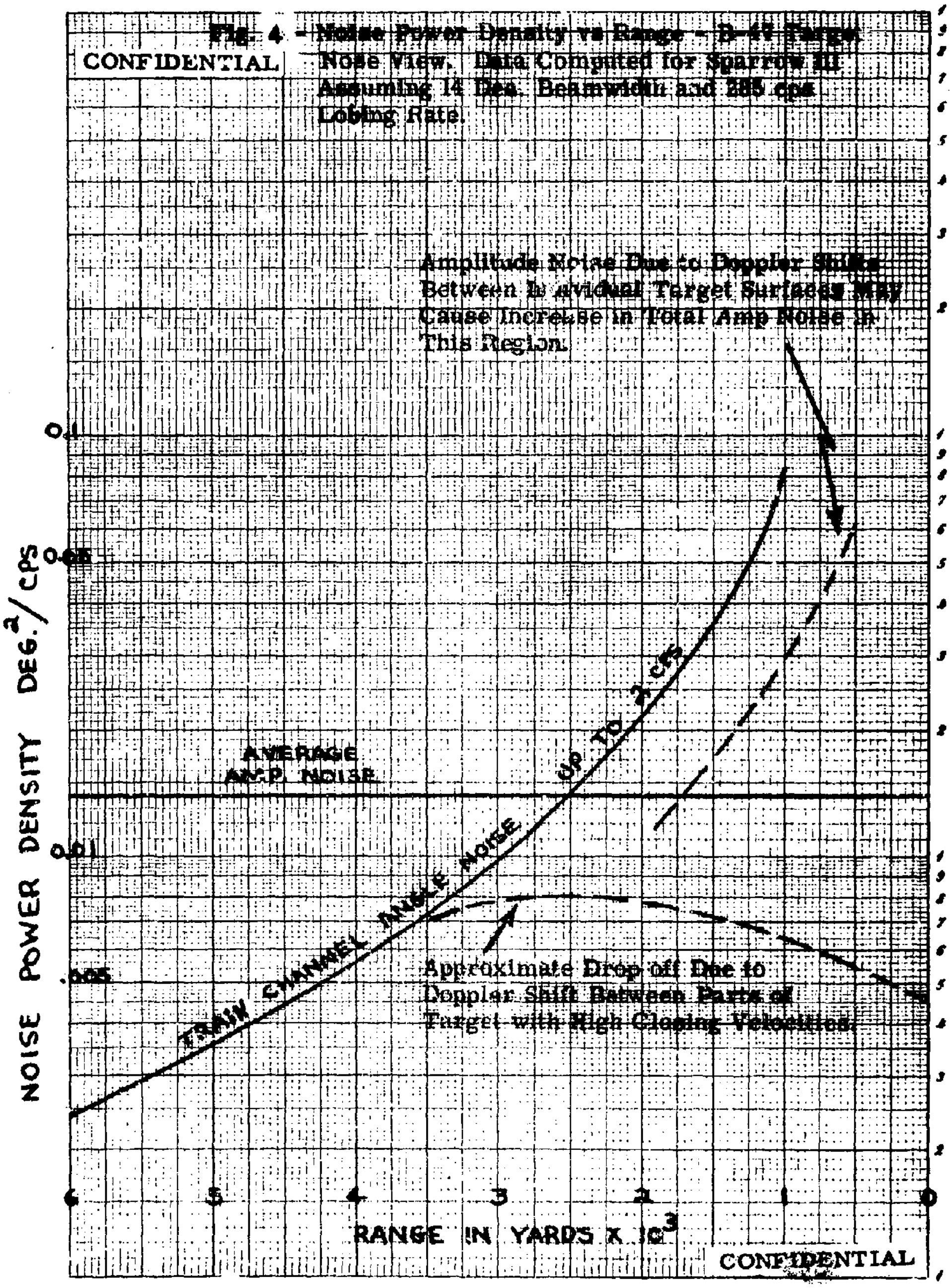

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Fig. 5a - MODEL F4H-1 MISSILE TRAJECTORY TIME HISTORY LEFT - HAND AFT MISSILE

Initial Conditions
1 - Ejector Type Launch
2 - Controls Locked
3 - Mach Number = 0.80
4 - H_p = 45,000 Ft
5 - N_Z = 1g
6 - $\dot{\Theta}_o$ = 0.312 Rad/Sec
7 - $\dot{\Psi}_o$ = 0 Rad/Sec
8 - ϕ_N = 0 Deg
9 - Ignition at T = 0.1 Sec
10 - Ejector Impulse = 14.5 g's (Max)
11 - Rocket Thrust = 6875 Lbs (Net) $(T-D_{AVE})$

Note:
Reference Axis is Free Airstream at Zero Time

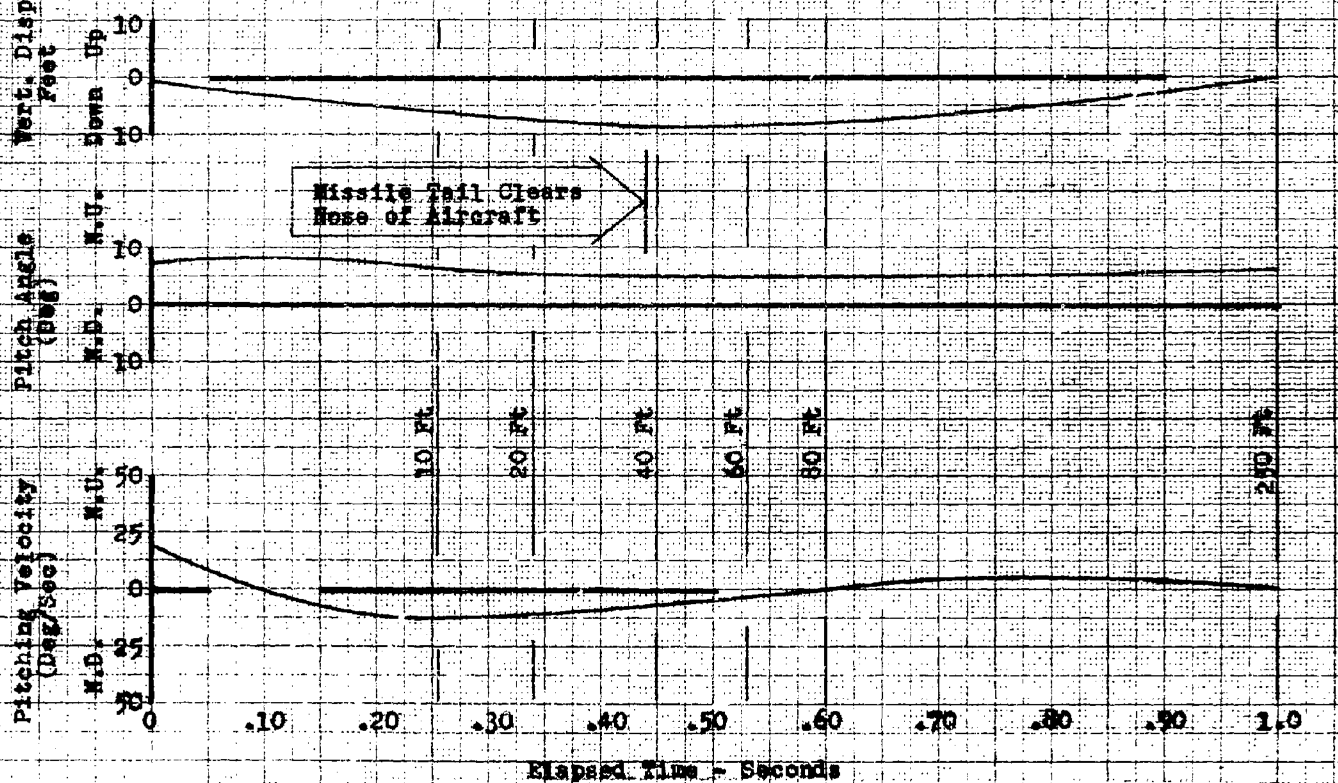

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Fig. 5b - MODEL P4B-1 MISSILE TRAJECTORY TIME HISTORY LEFT & HAND AFT MISSILE

Initial Conditions

1 - Ejector Type Launch
2 - Controls Locked
3 - Mach Number = 0.80
4 - H_p = 45,000 Ft
5 - N_{z_o} = 1g
6 - ω_{y_o} = 0.312 Rad/Sec
7 - $\dot{\psi}_o$ = 0 Rad/Sec
8 - ψ_o = 0 Deg
9 - Ignition at T = 0.1 Sec
10 - Ejector Impulse = 14.5 g's (Max)
11 - Rocket Thrust = 6825 Lbs (Net) (T-D_{AVE})

Notes;
Reference Axis is Free
Airstream at Same Time

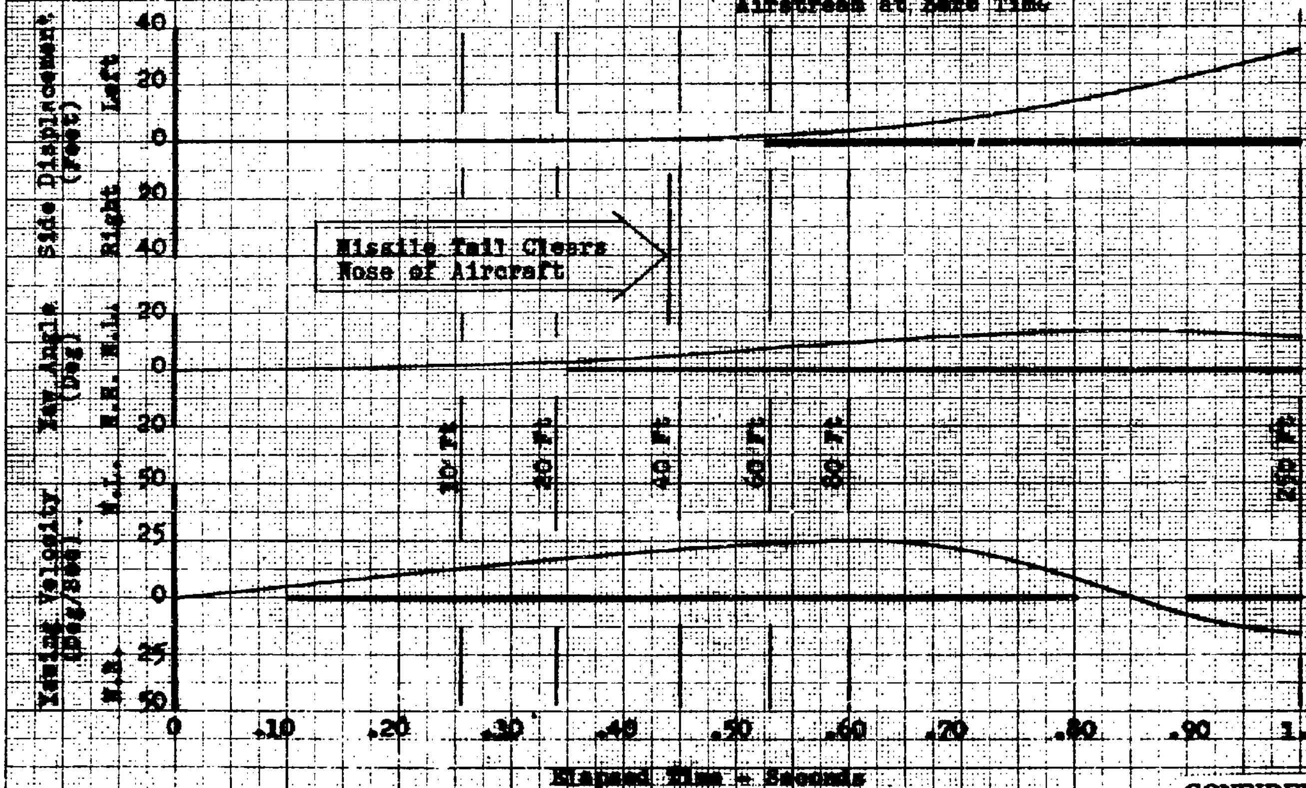

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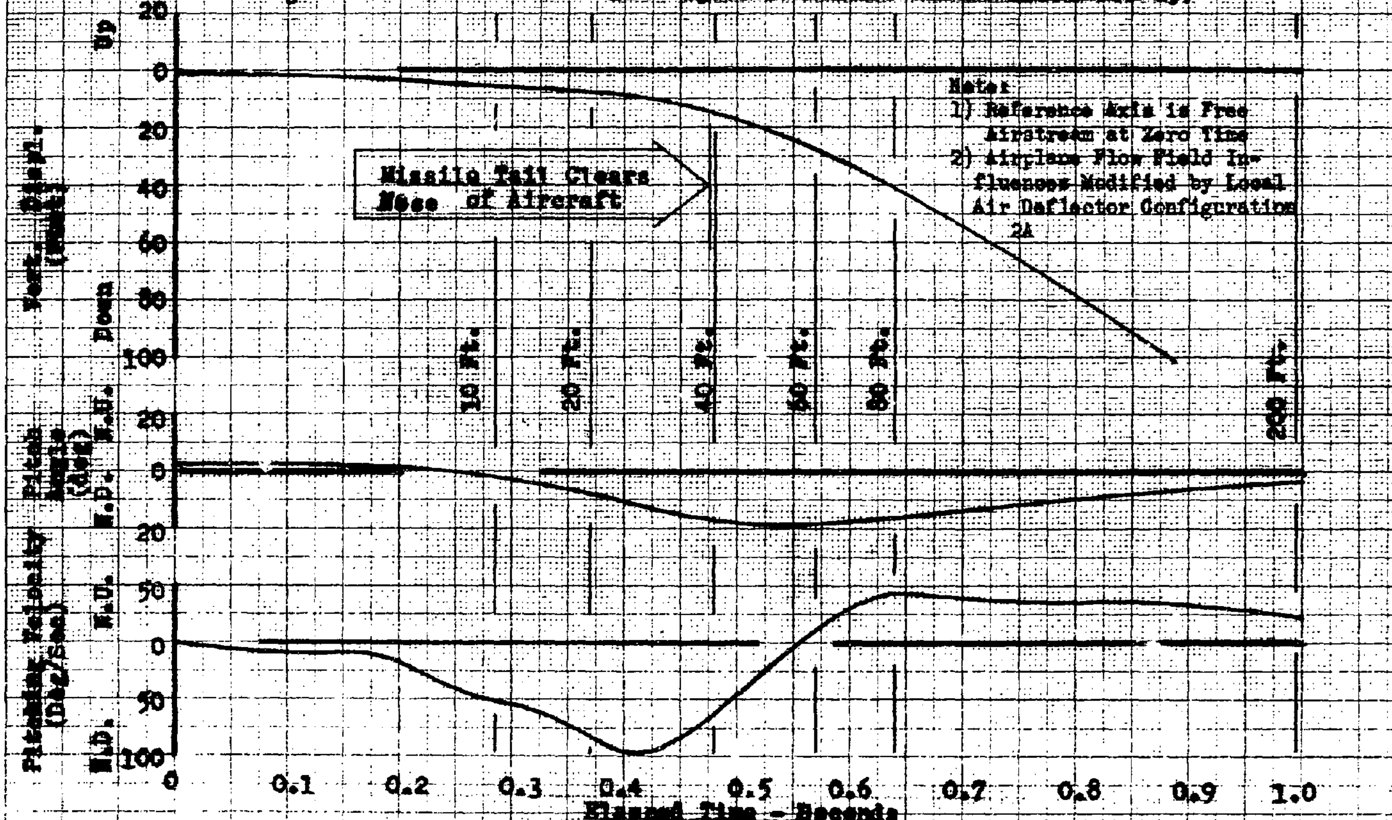
Fig. 6a - MODEL F4H-1 MISSILE TRAJECTORY TIME HISTORY LEFT - HAND AFT MISSILE

Initial Conditions

1 - Ejector Type Launch
2 - Controls Locked
3 - Mach Number = 0.95
4 - H_p = 10,000 Ft
5 - N_{Z_o} = 3 g's
6 - $\dot{\theta}_o$ = 0 Rad/Sec
7 - Ψ = 0 Rad/Sec
8 - α_o = 0 Deg
9 - Ignition at t = .10 Sec
10 - Ejector Impulse = 14.5 g's (Max)
11 - Rocket Thrust = 6750 Lbs. (T-O Avg)
12 - Ejector Moment = 600 Ft-Lbs (Nose-up)



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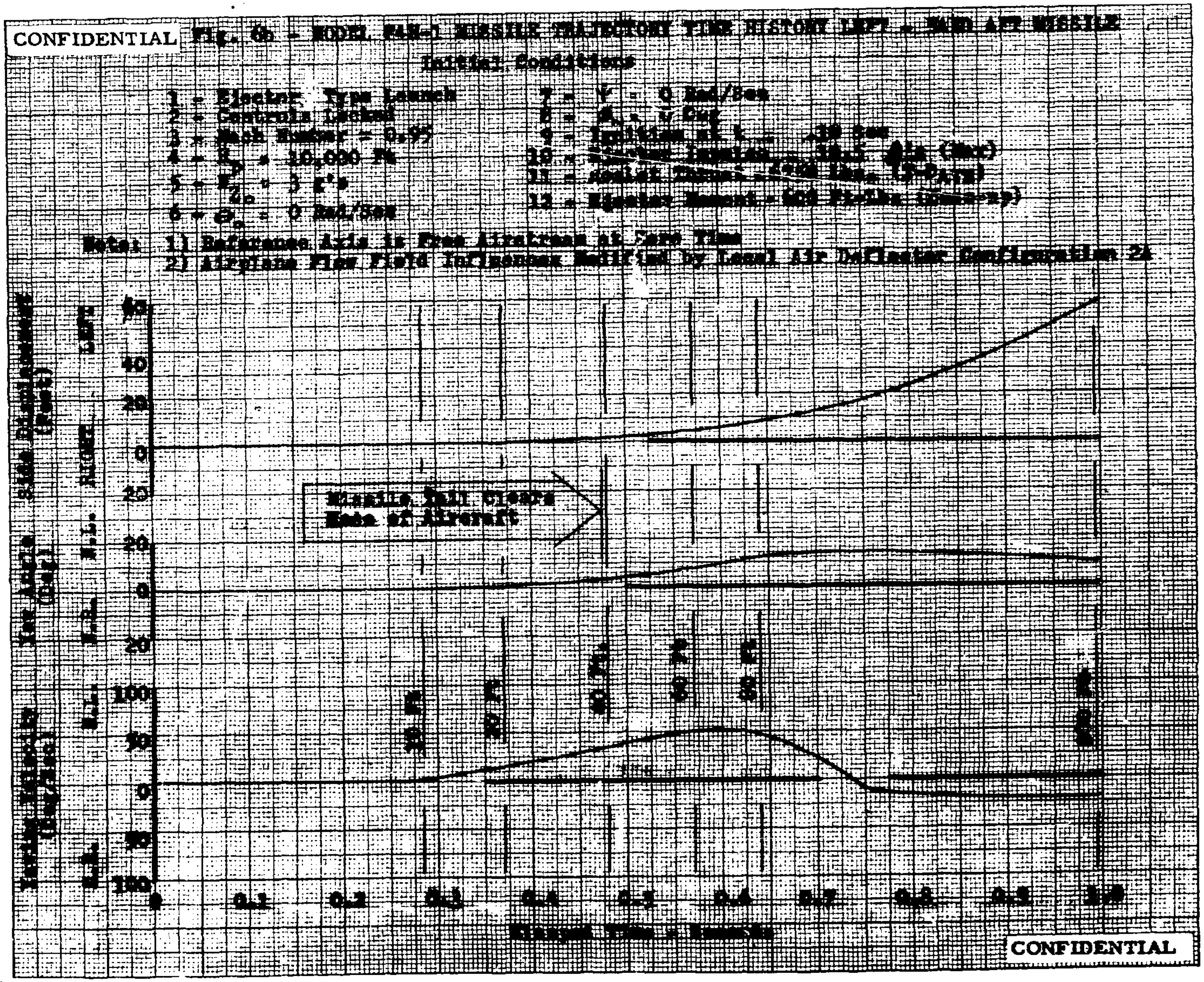
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Initial Conditions
1 - Ejector Type Launch
2 - Controls Locked
3 - Mach Number = 0.95
4 - = 10,000 Ft
6 - = 0 Rad/Sec
7 - = 0 Rad/Sec
Note:
Missile Tail Clears
Nose of Aircraft
LEFT
RIGHT
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
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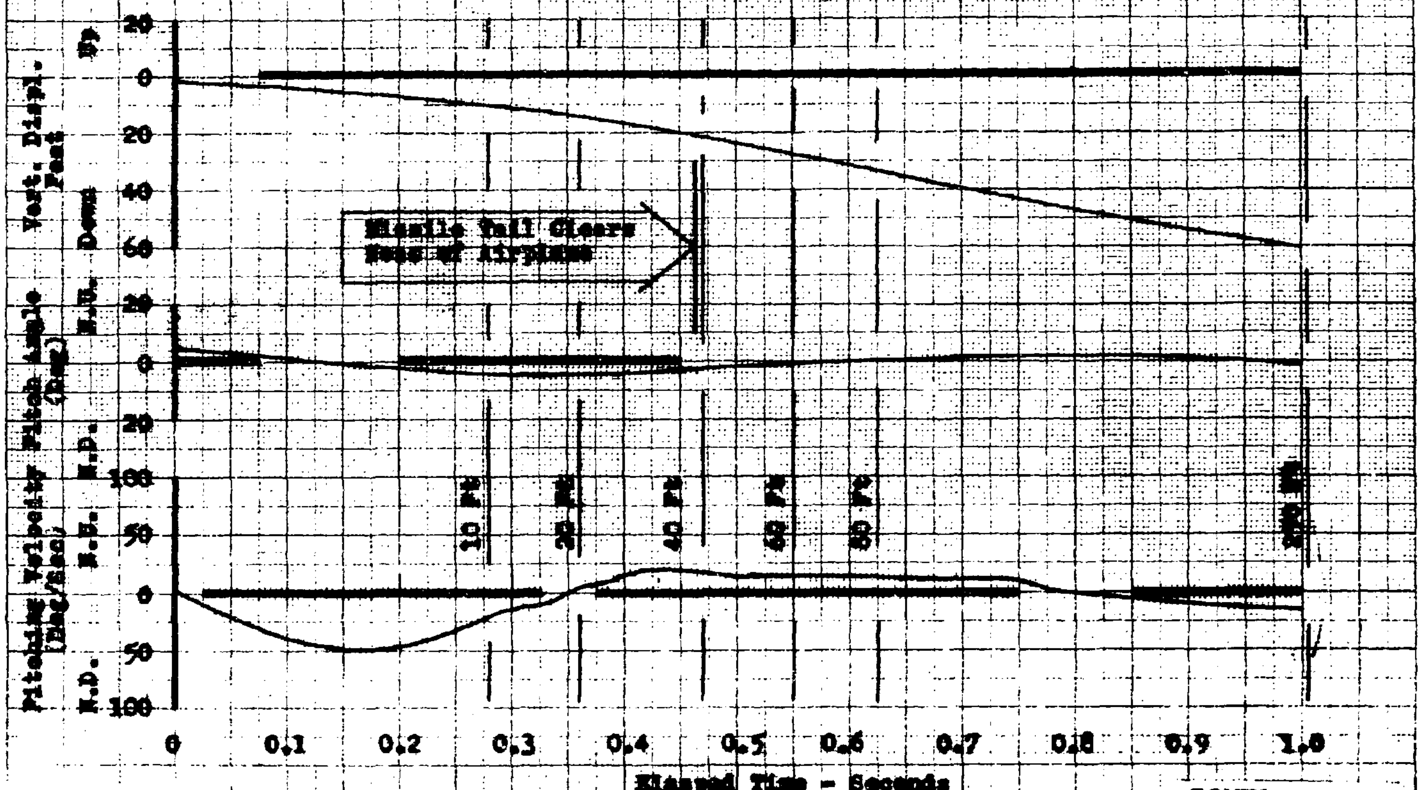
Fig. 7a- MODEL F4H-1 MISSILE TRAJECTORY TIME HISTORY LEFT - HAND AFT MISSILE

Initial Conditions

1 - Ejection Type Launch
2 - Controls Locked
3 - Mach Number = 1.87
4 - Hp = 55,000 Ft
5 - n_{z_0} = 1.0g
6 - $\dot{\theta}_0$ = 0 Deg/Sec
7 - $\dot{\psi}_0$ = 0 Deg/Sec
8 - ϕ_0 = 0 Deg
9 - Ignition at T = .1 Sec
10 - Ejector Impulse = 14.5 g's
11 - Rocket Thrust = 6600 Lbs (Net)(T - D_{Avg})

Note: Reference Axis is Free Airstream at Zero Time



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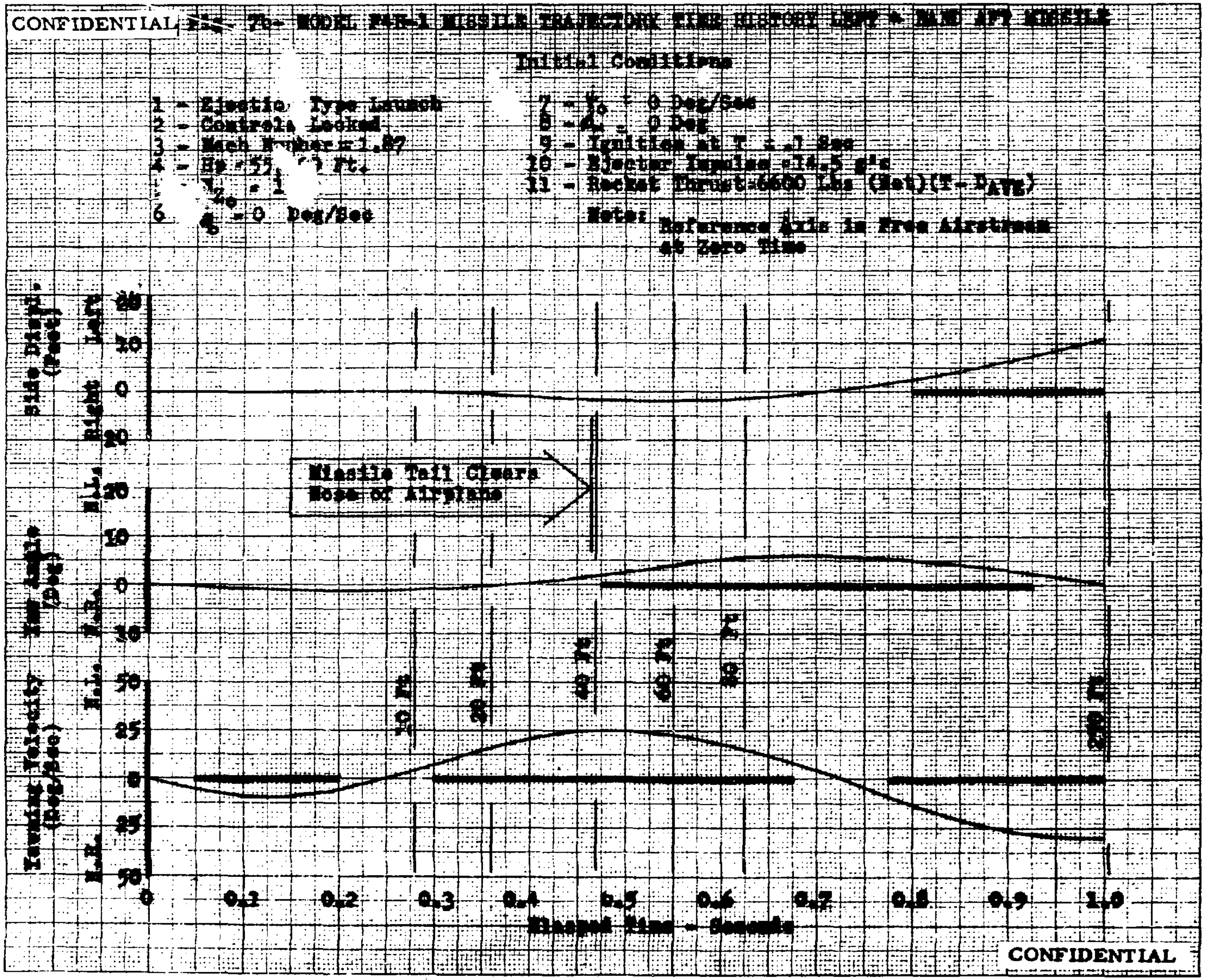

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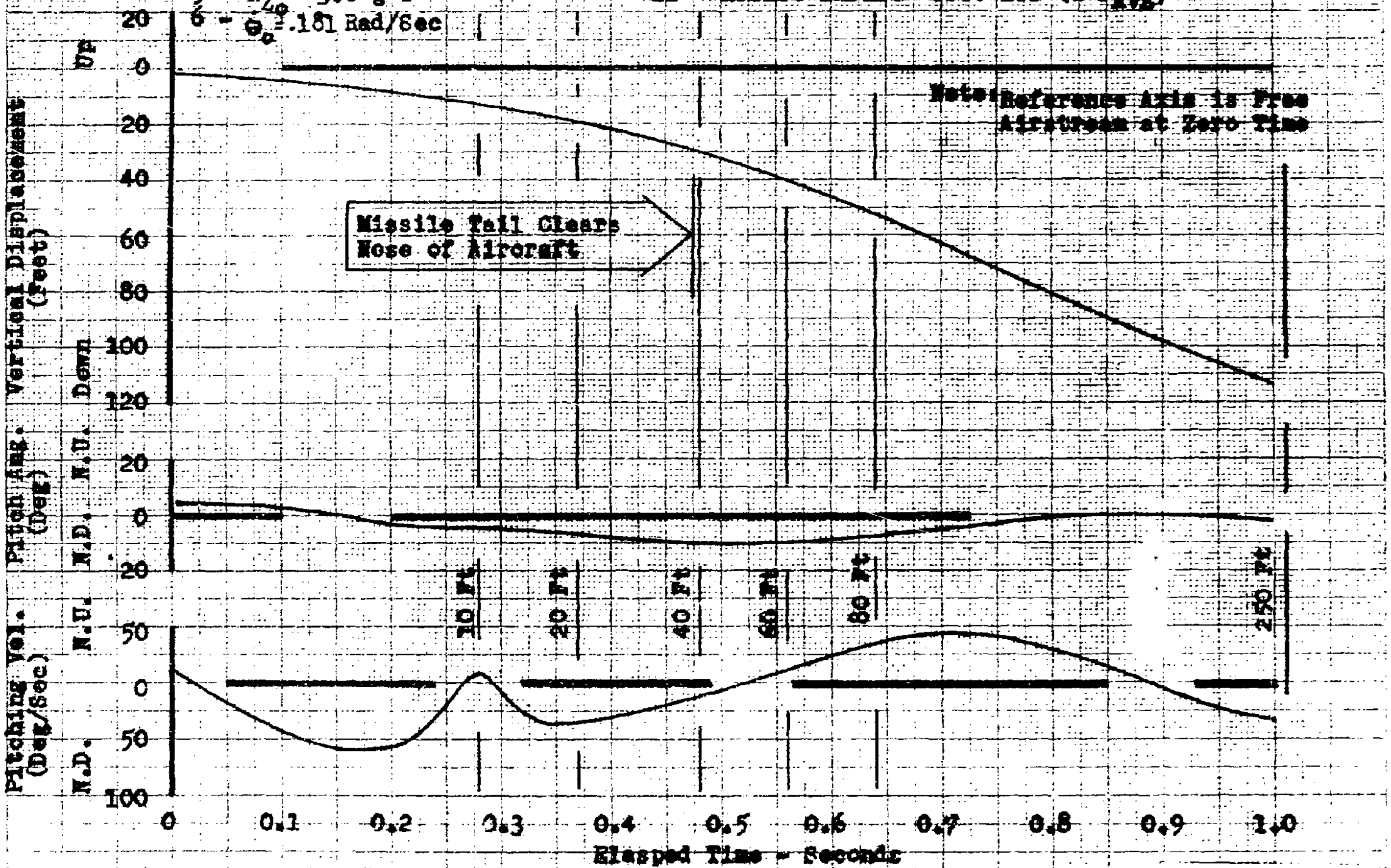
Fig. 8a- MODEL F4H-1 MISSILE TRAJECTORY TIME HISTORY LEFT-HAND AFT MISSILE

Initial Conditions

1 - Ejection Type Launch
2 - Controls Locked
3 - Mach Number = 1.87
4 - H_p = 35,000 Ft
5 - N_{Z_o} = 3.0 g's
6 - $\dot{\theta}_o$ = .181 Rad/Sec
7 - $\dot{\psi}_o$ = 0 Rad/Sec
8 - ϕ_N = 0 Deg
9 - Ignition at T = 0.1 Sec
10 - Ejector Impulse = 14.5 g's (Max)
11 - Rocket Thrust = 6600 Lbs (T-D$_{AVG}$)



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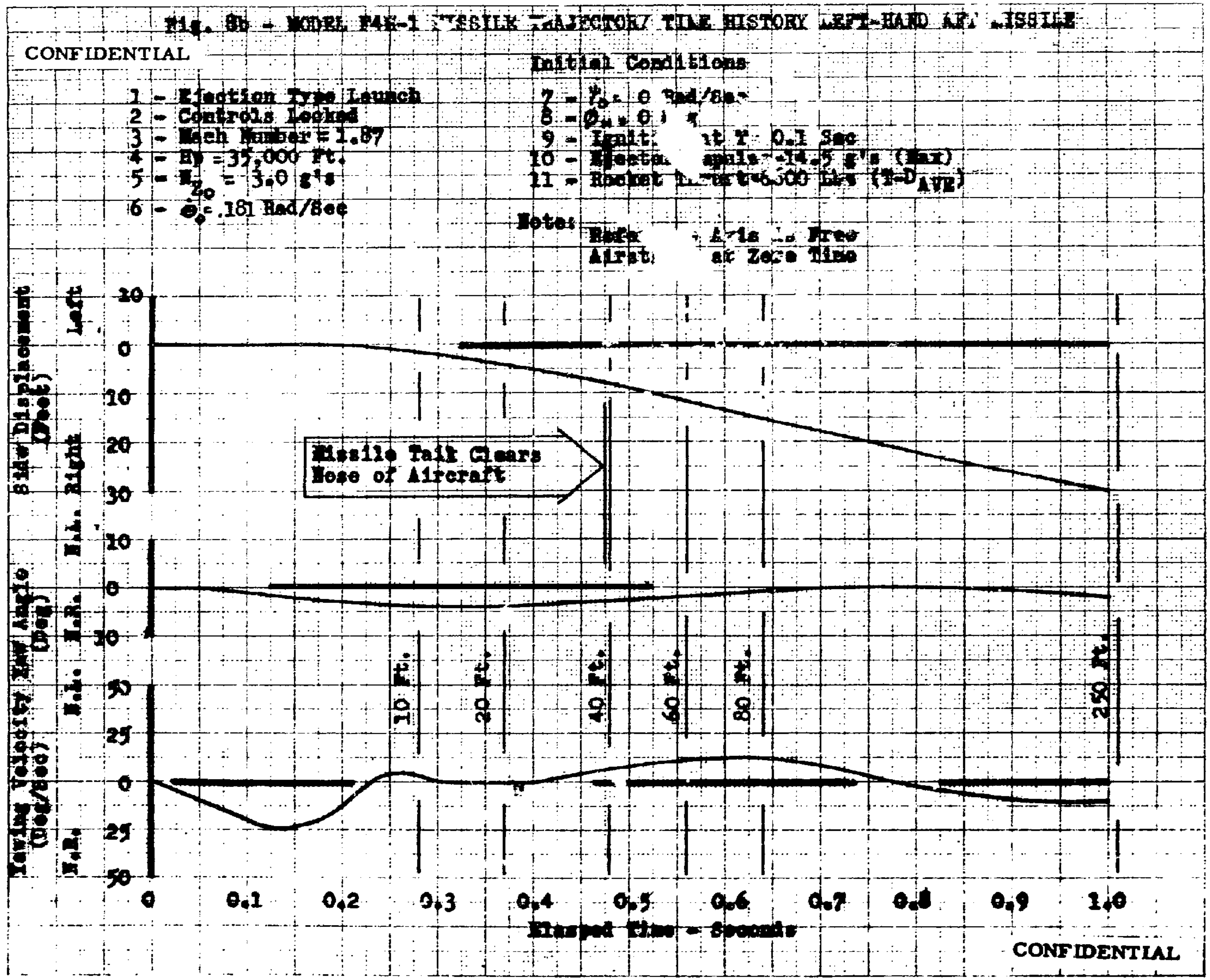
Fig. 8b - MODEL F4H-1 MISSILE TRAJECTORY TIME HISTORY LEFT-HAND AFT MISSILE
CONFIDENTIAL
Initial Conditions
1 - Ejection Type Launch
2 - Controls Locked
3 - Mach Number = 1.87
4 - Hp = 35,000 Ft.
5 - N_{Z_0} = 3.0 g's
6 - $\dot{\theta}_c$ = .181 Rad/Sec
7 - $\dot{\psi}_o$ = 0 Rad/Sec
8 - ϕ = 0
9 - Ignit. at T 0.1 Sec
10 - Ejecta. 14.5 g's (Max)
11 - Rocket 6,300 Lbs (T-D AVE)
Note:
Airst. at Zero Time
Side Displacement (Feet)
Left
Right
N.L.
N.R.
Yaw Angle (Deg)
Yawing Velocity (Deg/Sec)
Missile Tail Clears Nose of Aircraft
10 Ft.
20 Ft.
40 Ft.
60 Ft.
80 Ft.
250 Ft.
Elapsed Time - Seconds
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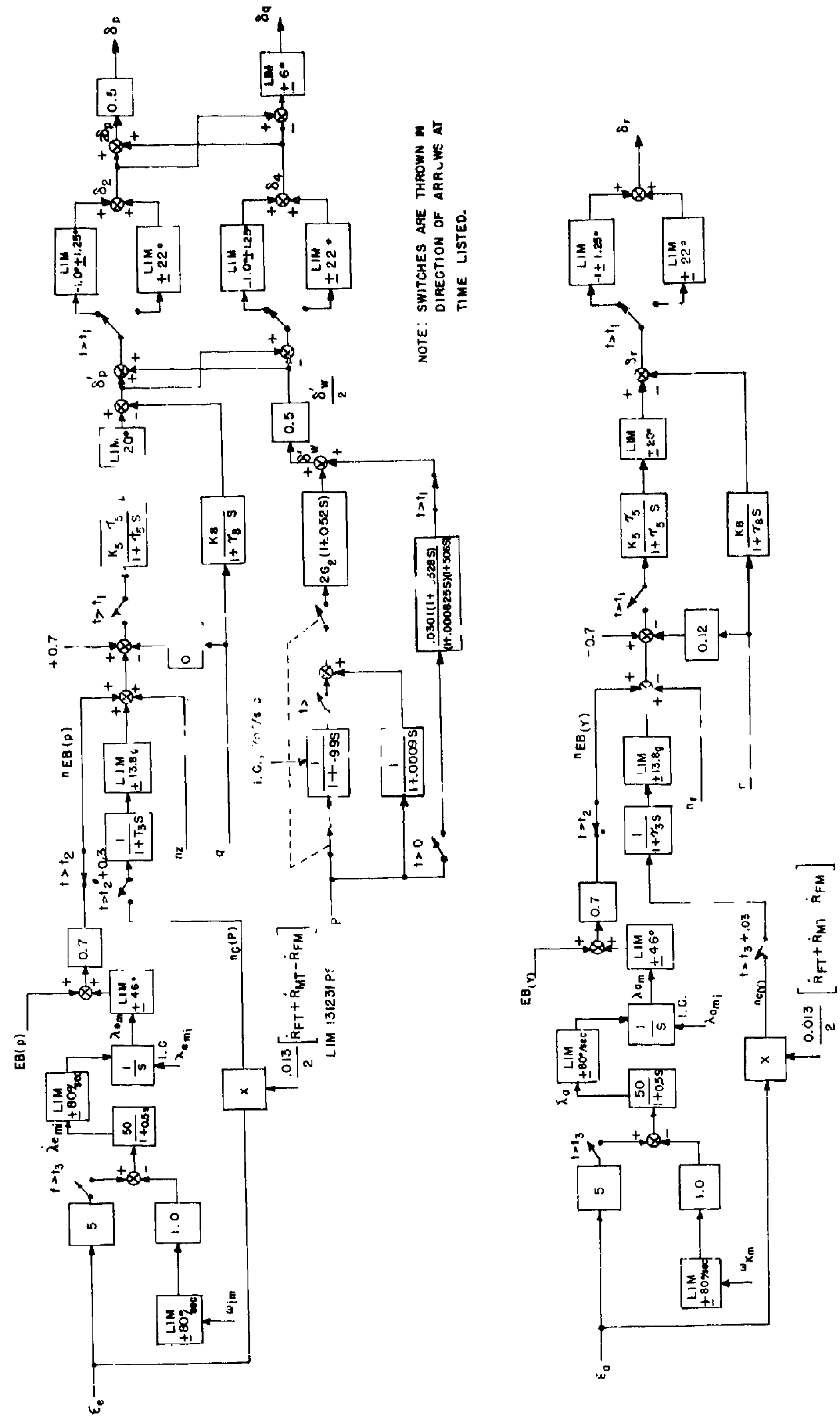

Fig. 9 - Sparrow III Autopilot and Seeker Block Diagram

Fig. 10 - ORIENTATION OF ANGLES AND CO-EFFICIENTS

Note: Arrows indicate direction of positive quantities.

TAN $\alpha' = $ TAN α COS ϕ_N
SIN $\beta' = $ SIN α SIN ϕ_N

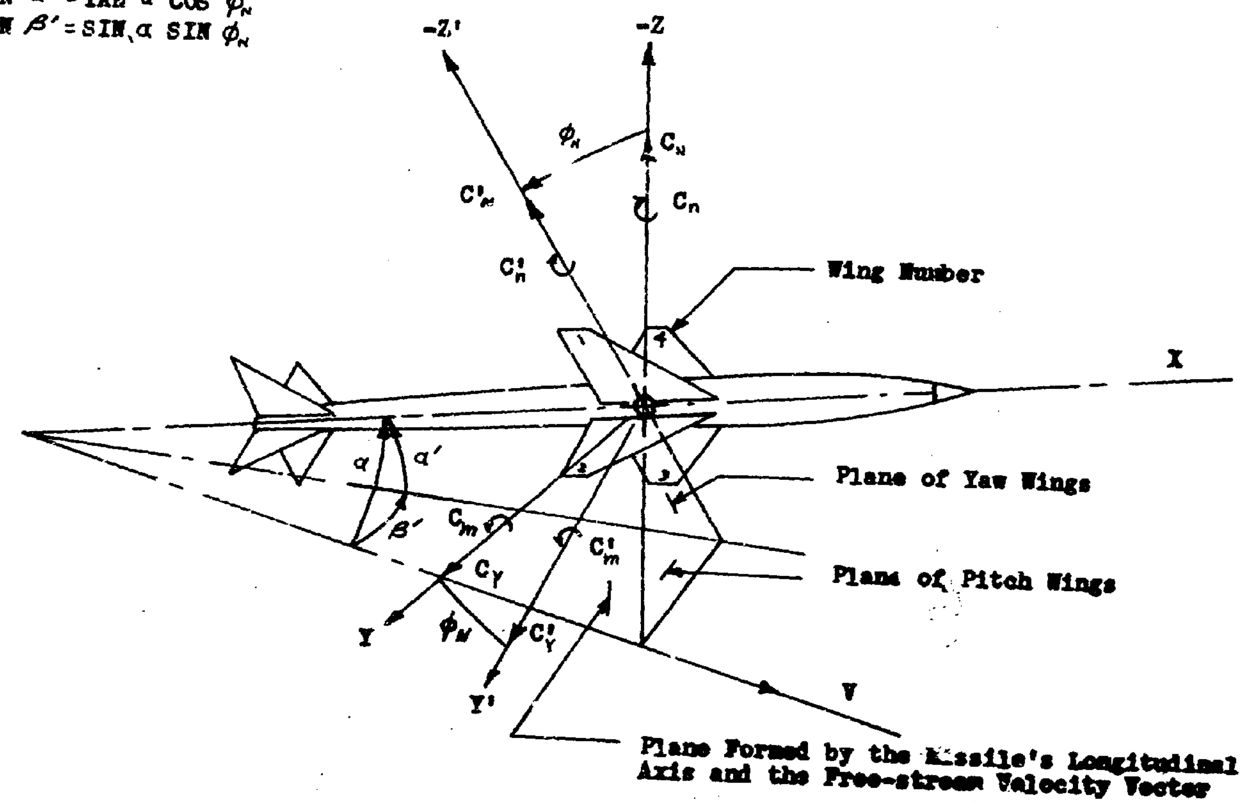

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Fig. 12- Sparrow III Zero Lift Drag
All Altitudes

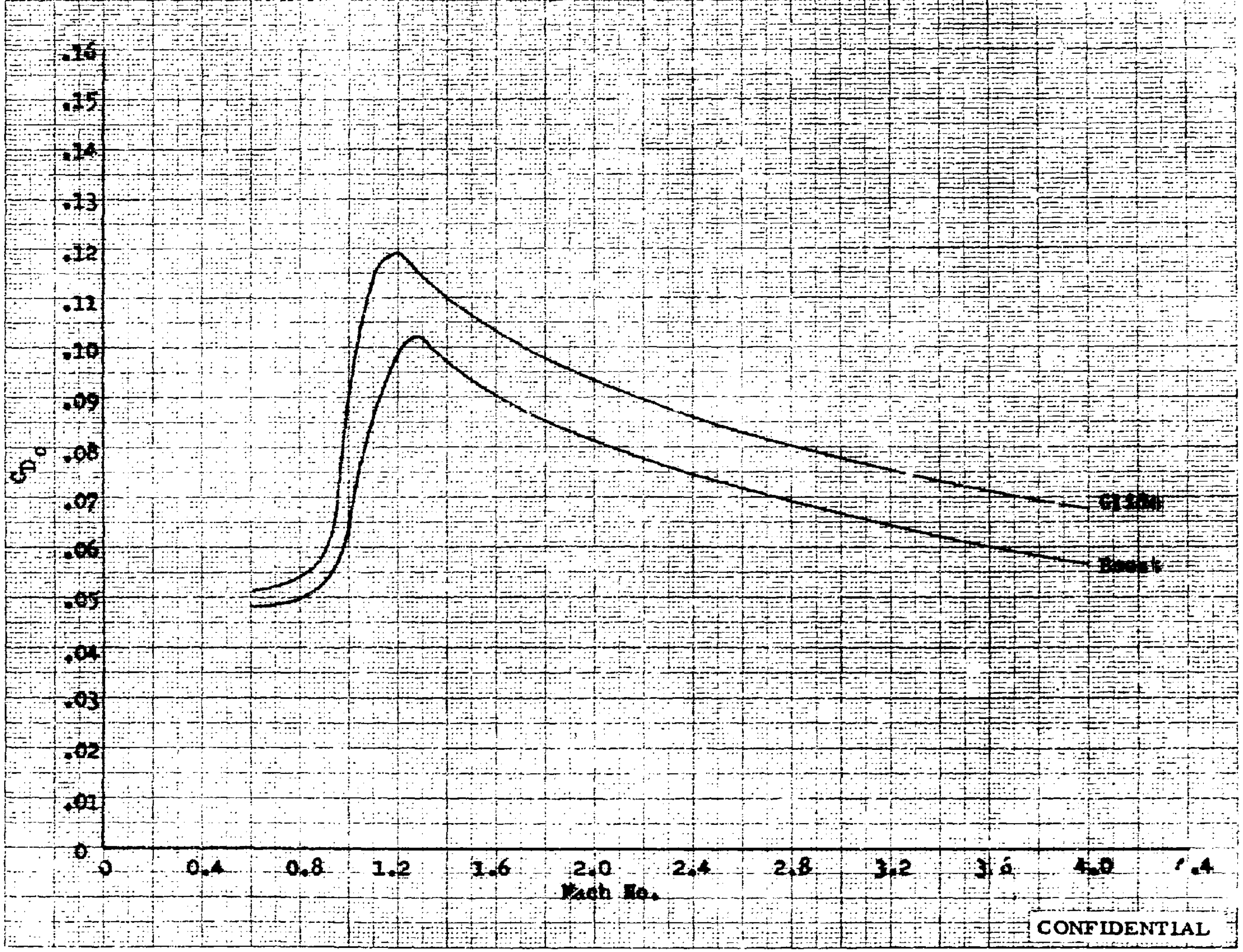

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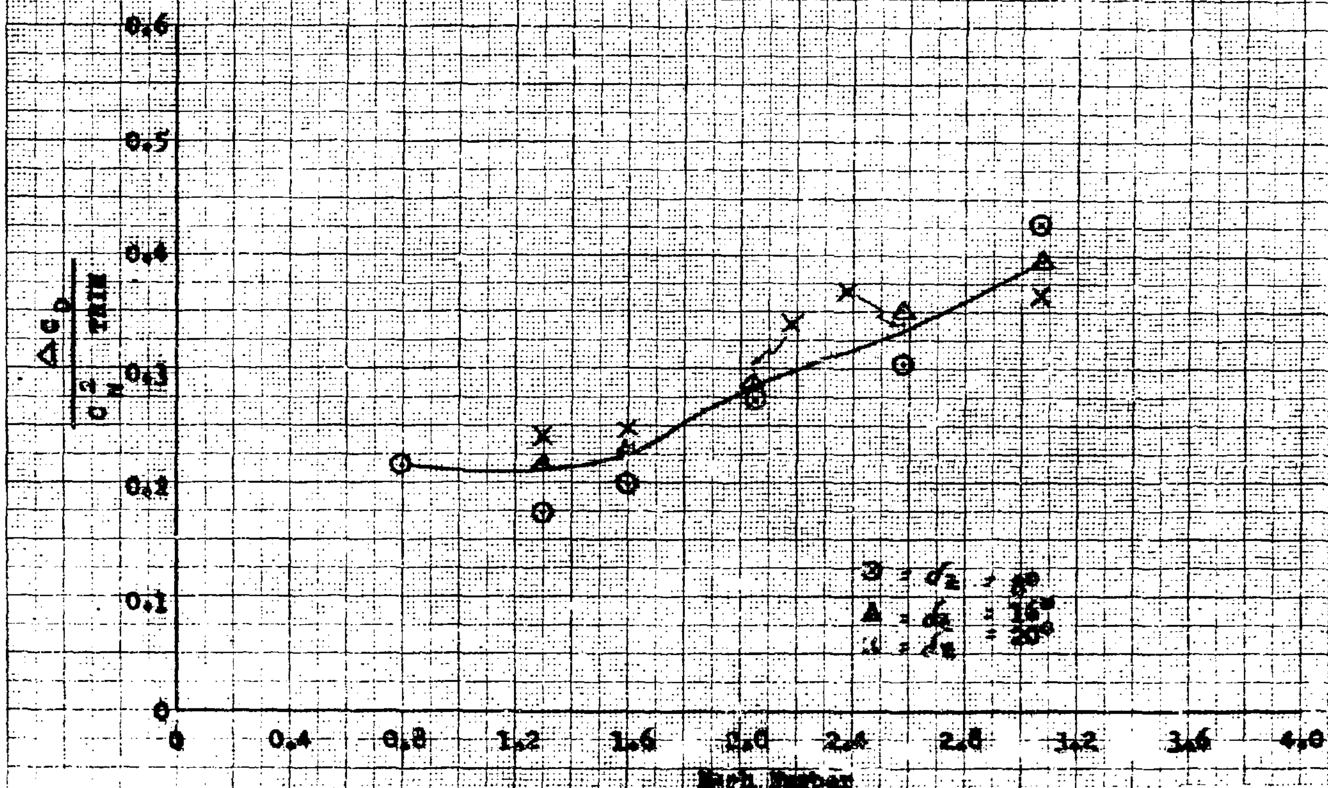
Fig. 12- Sparrow III Drag Due to Normal Force vs Mach Number for Various Wing Deflections, $\delta = 0°$



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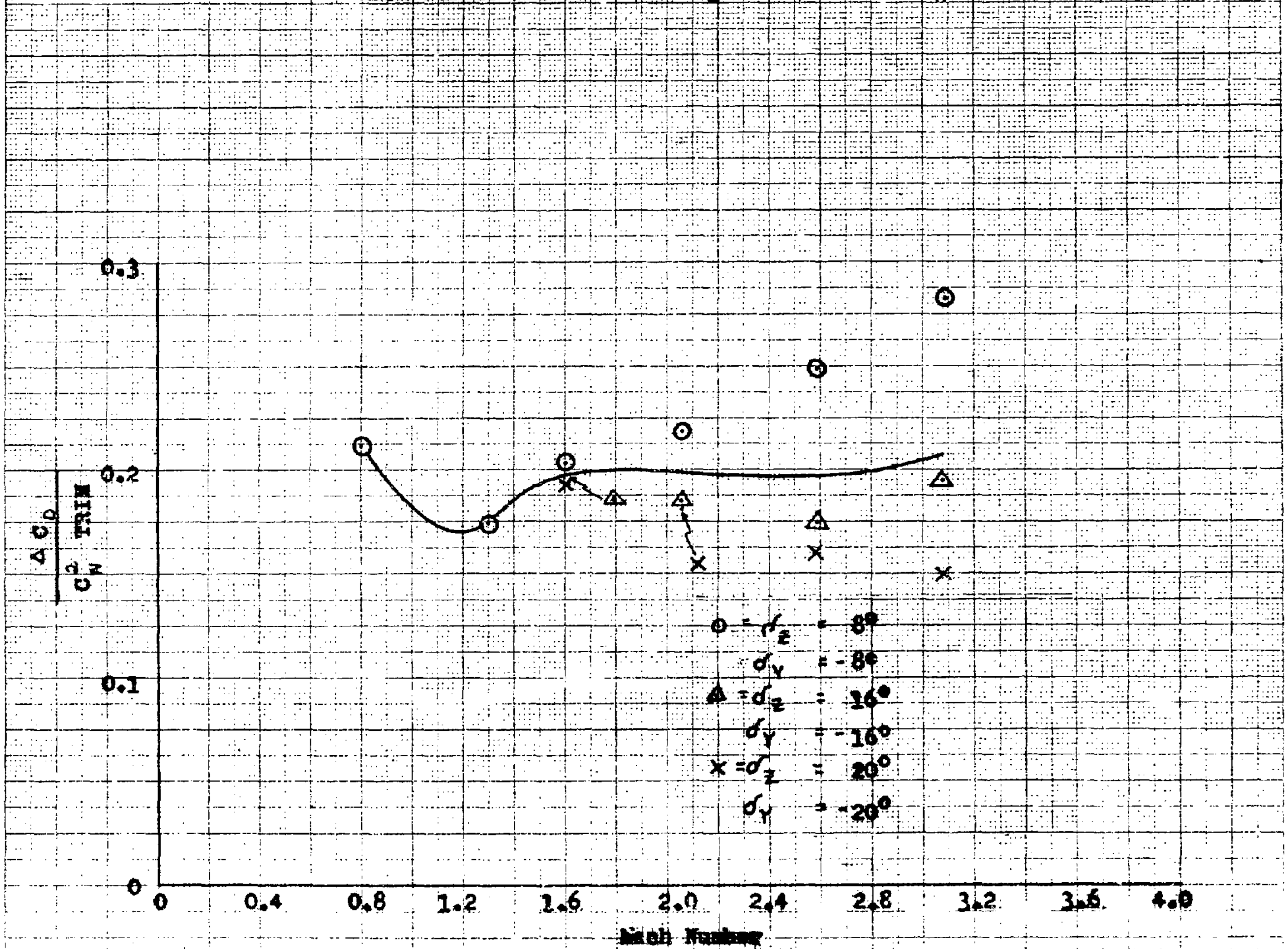

Fig. 13-Sparrow III Drag Due to Normal Forces vs Mach Number for Various Wing Deflections, $\phi_N = 45^\circ$

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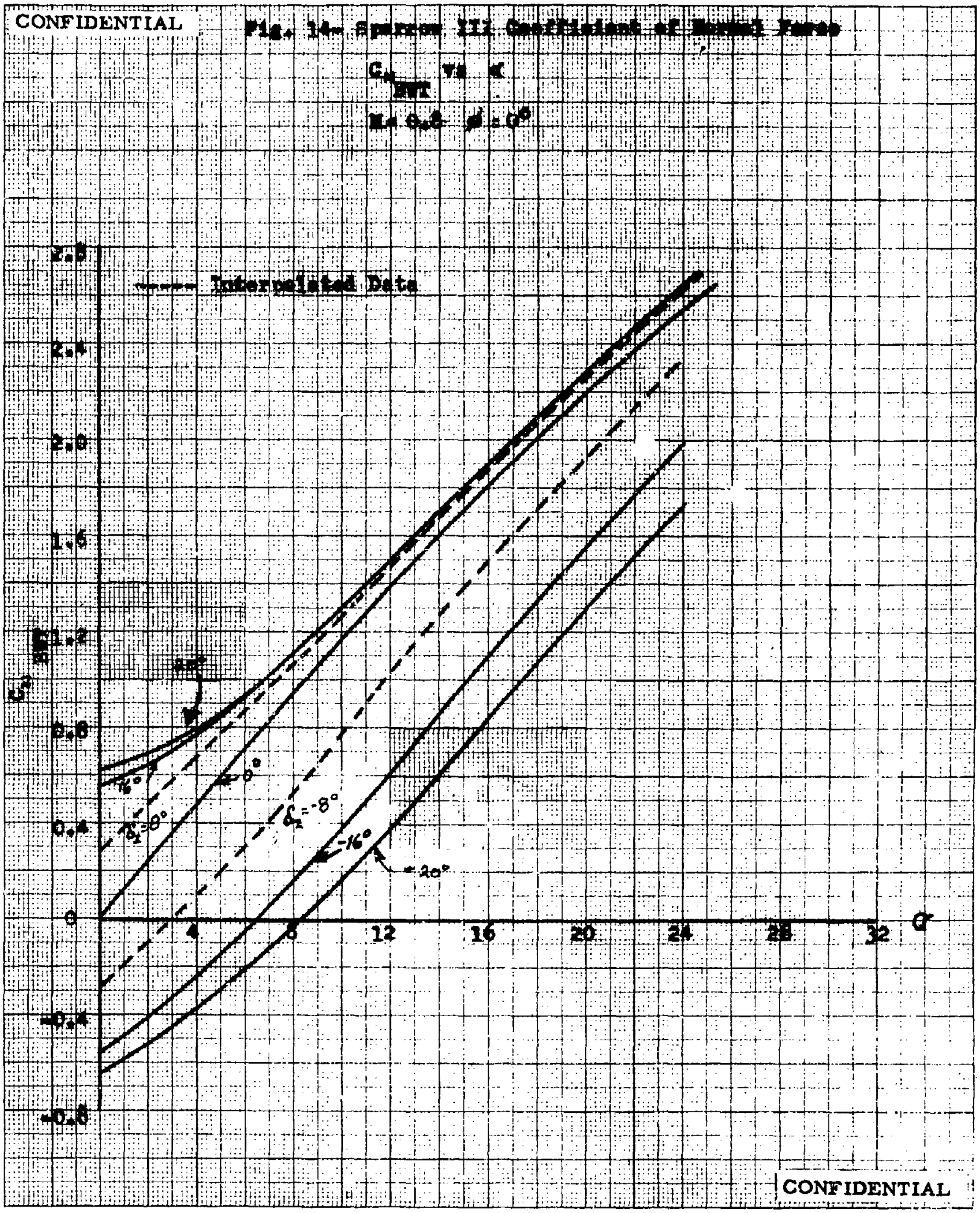

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Fig. 14- Sparrow III Coefficient of Normal Force
Interpolated Data
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
-0.4
-0.8
4
8
12
16
20
24
28
32
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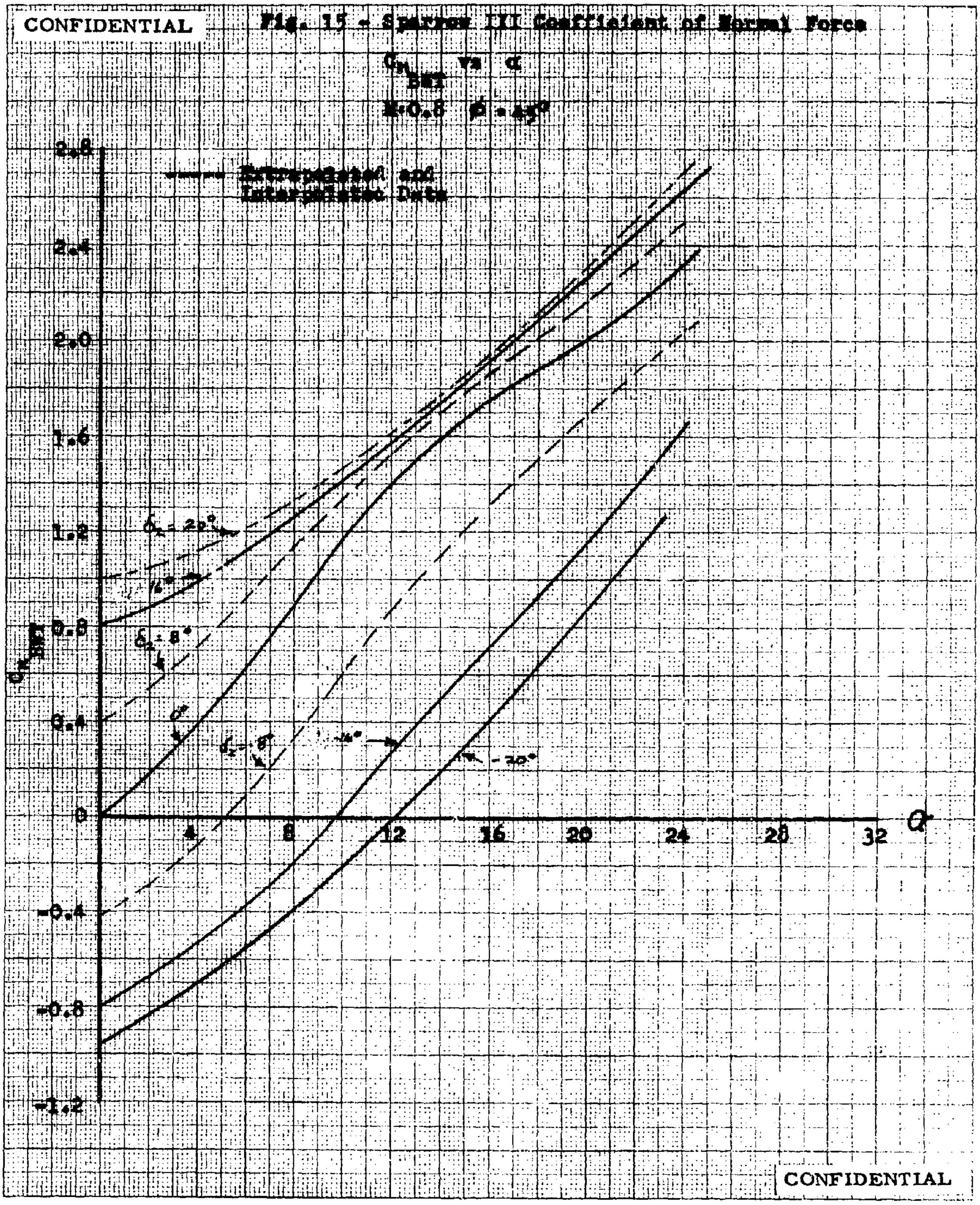

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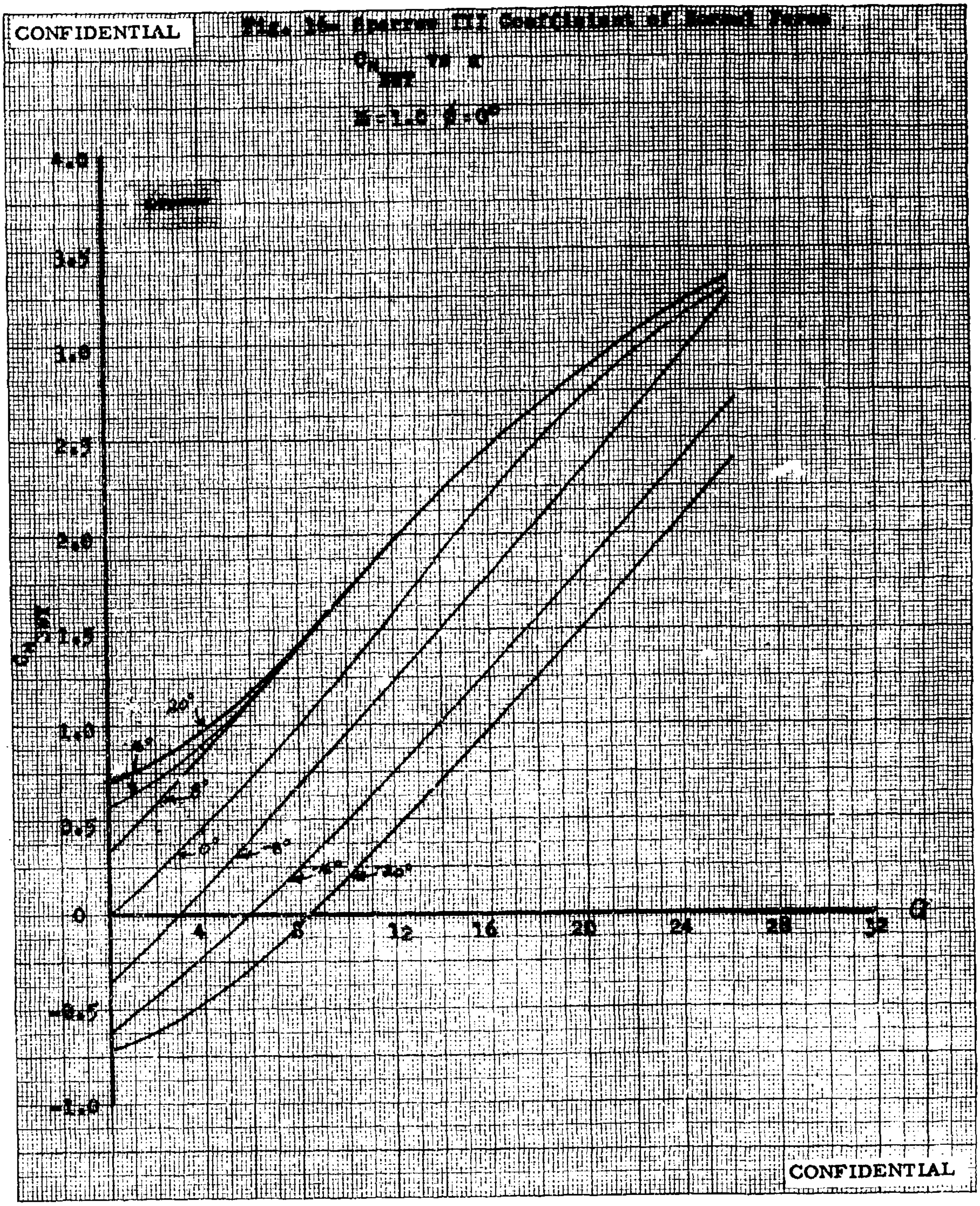

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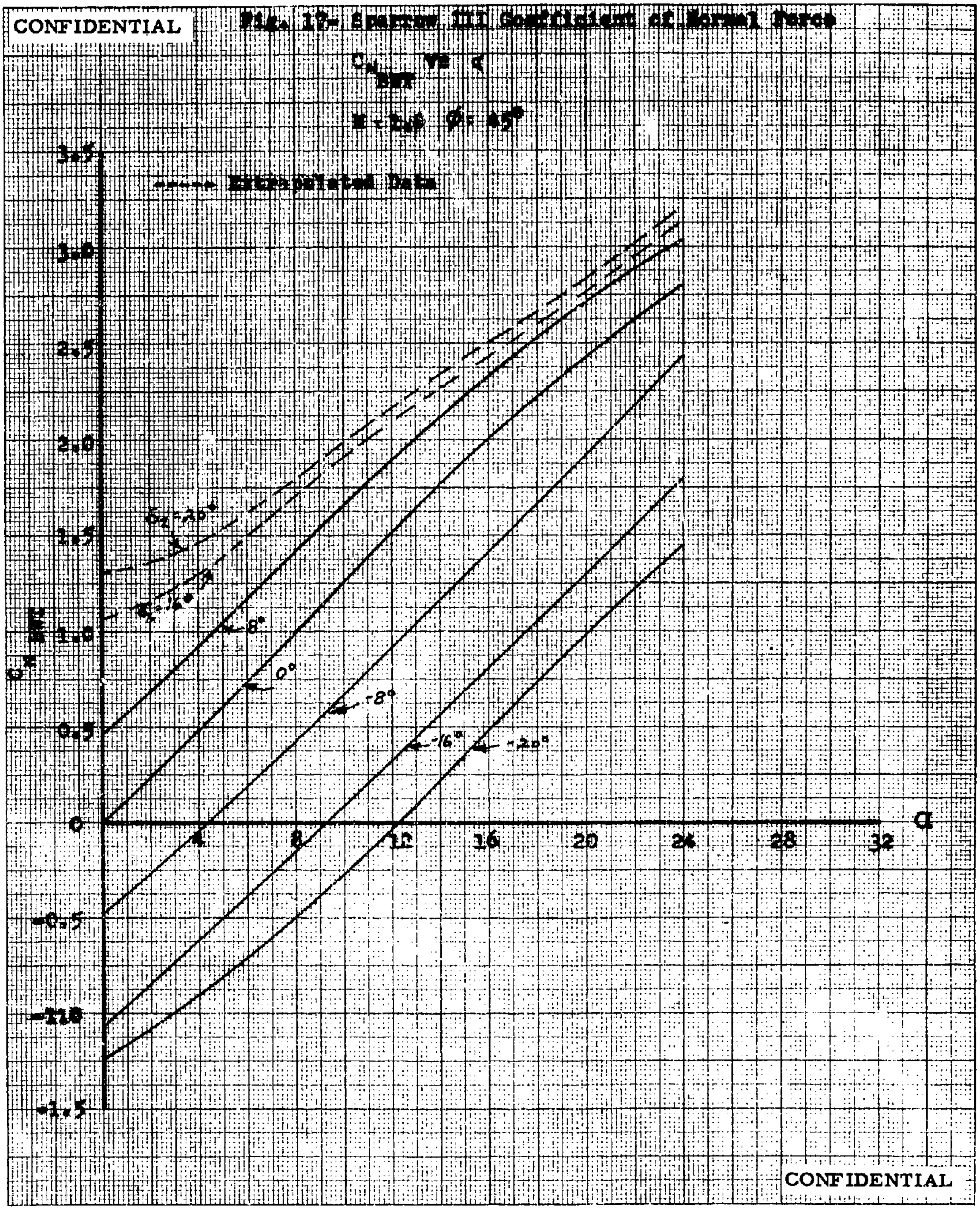

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Fig. 17- Sparrow III Coefficient of Normal Force
$C_{N_{BWT}}$ vs α
$\phi = 45°$
---- Extrapolated Data
$\delta_2 = 20°$
$\delta_2 = 16°$
8°
0°
-8°
-16°
-20°
C_N
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
4
8
12
16
20
24
28
32
α
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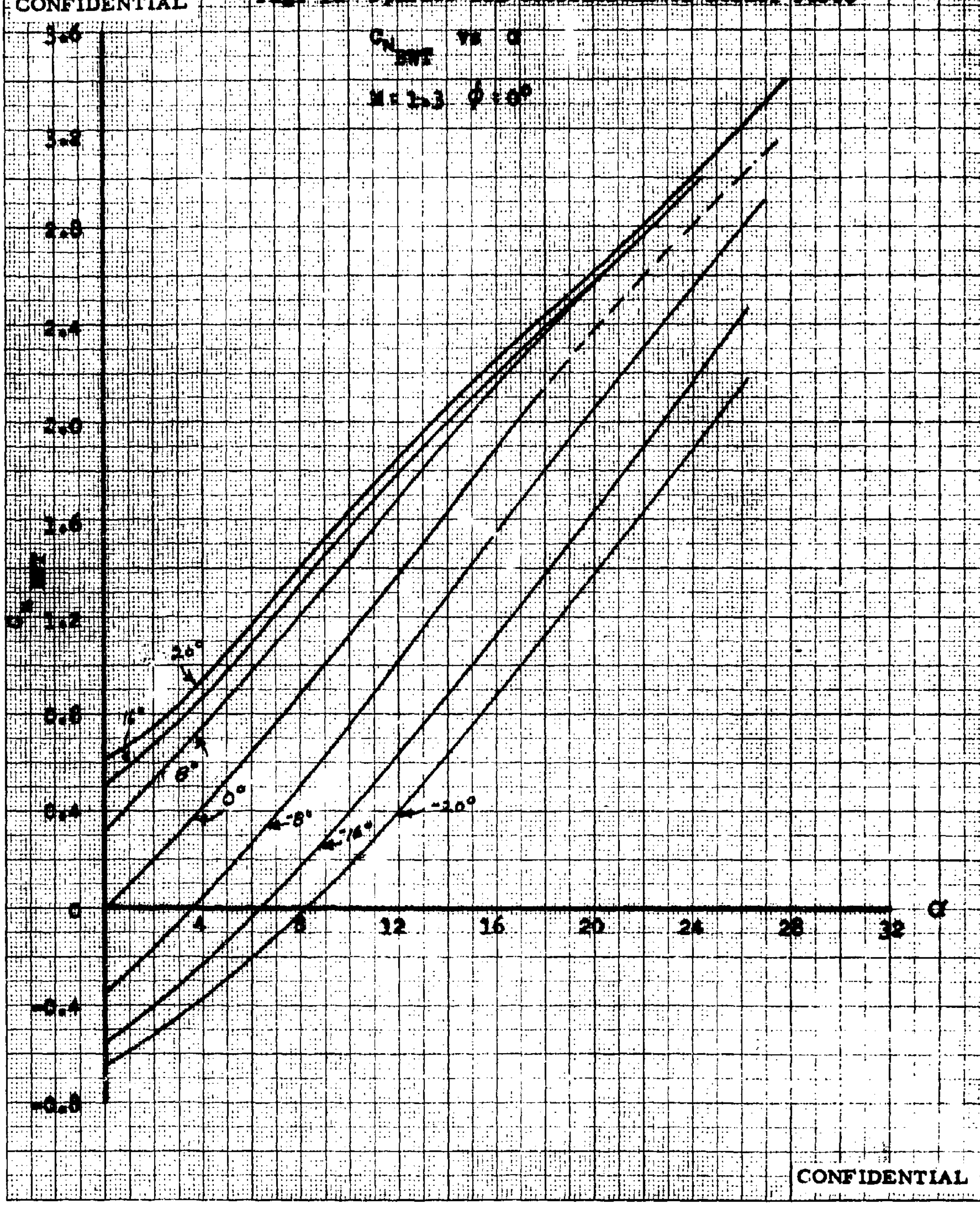
Fig. 18- Sparrow III Coefficient of Normal Force



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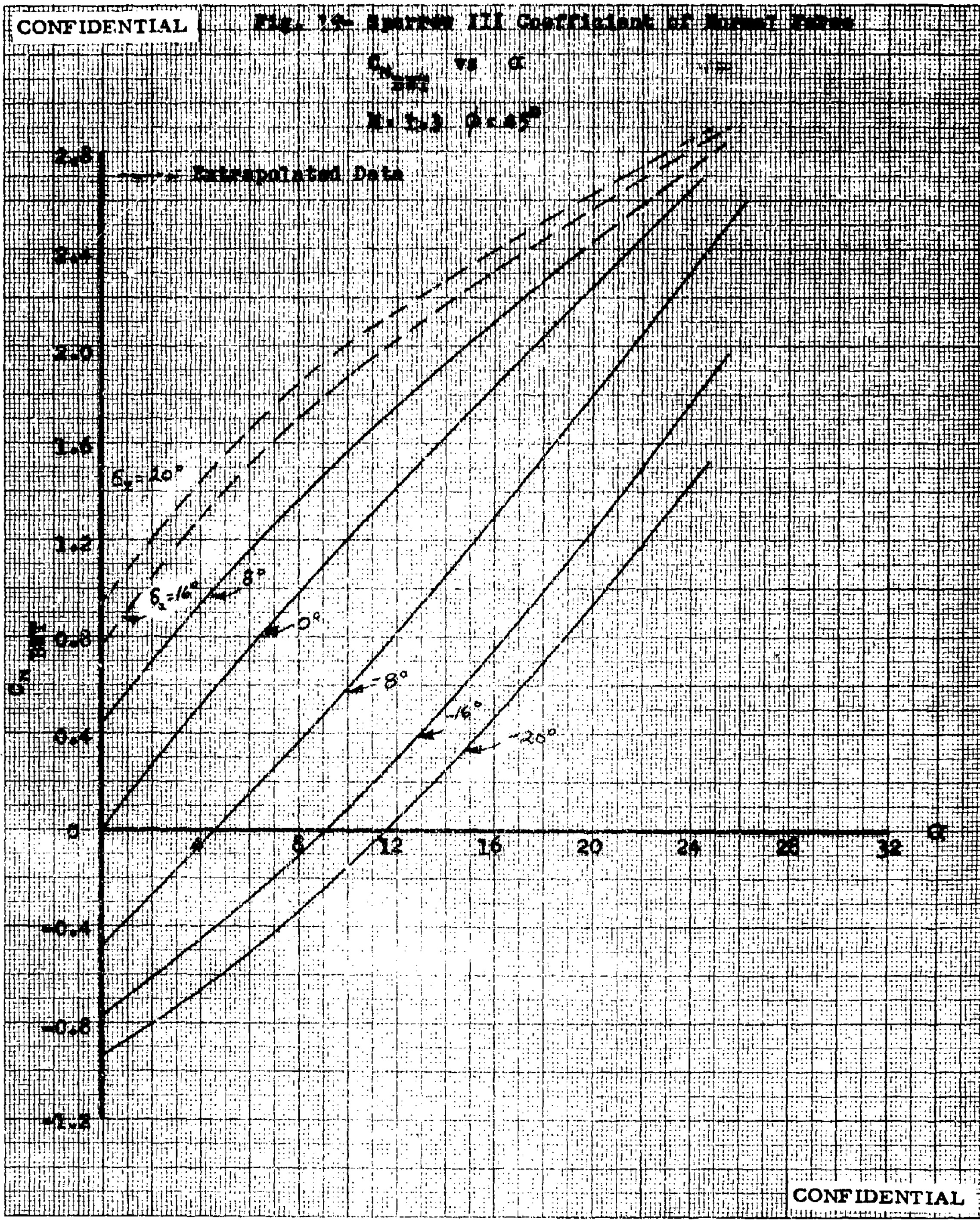

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Coefficient of
vs
Extrapolated Data
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
4
8
12
16
20
24
28
32
$\delta_r = 20°$
$\delta_r = 16°$
8°
0°
-8°
-16°
-20°
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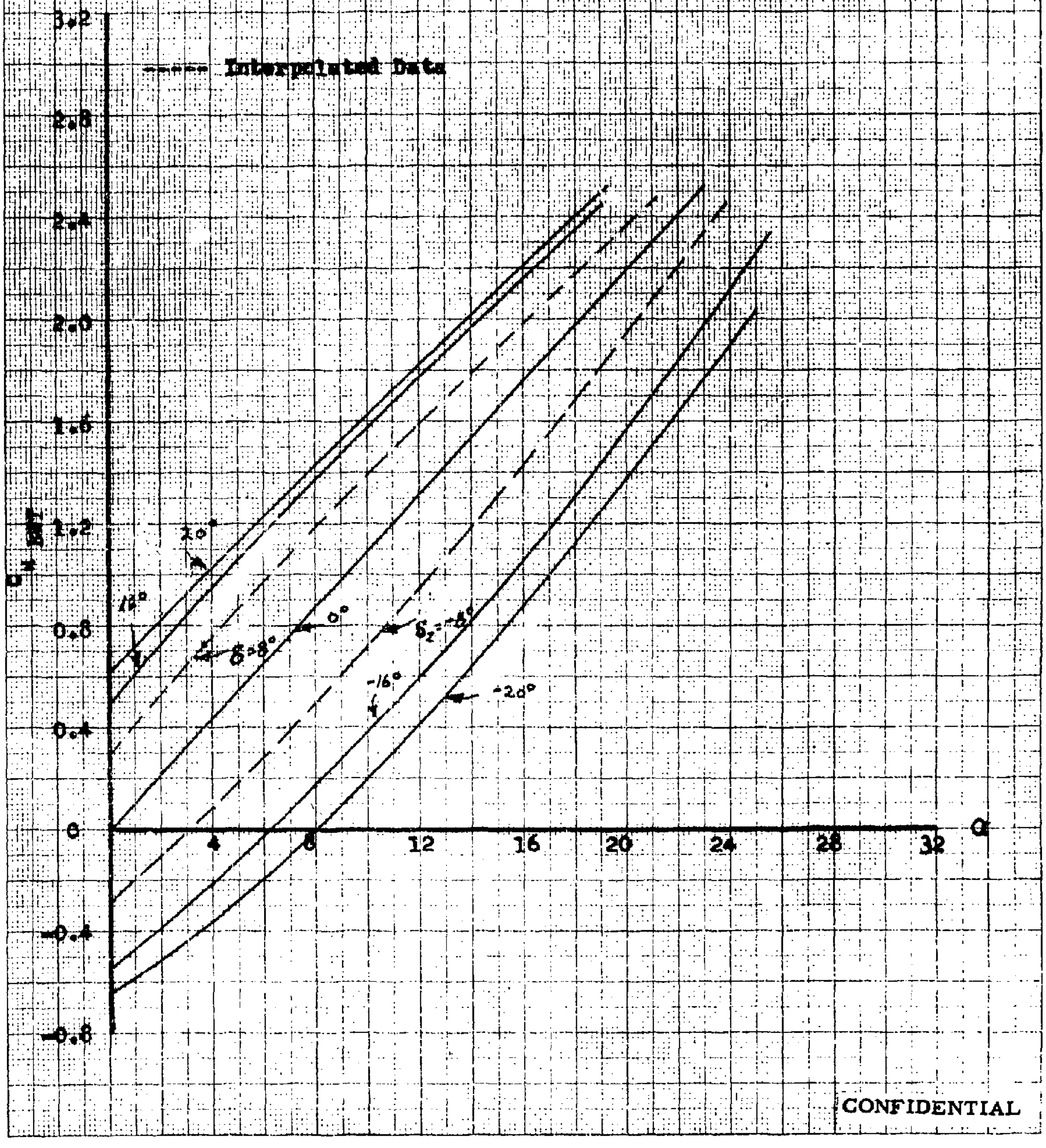
Fig. 20 - Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

M = 1.6 ϕ = 0°



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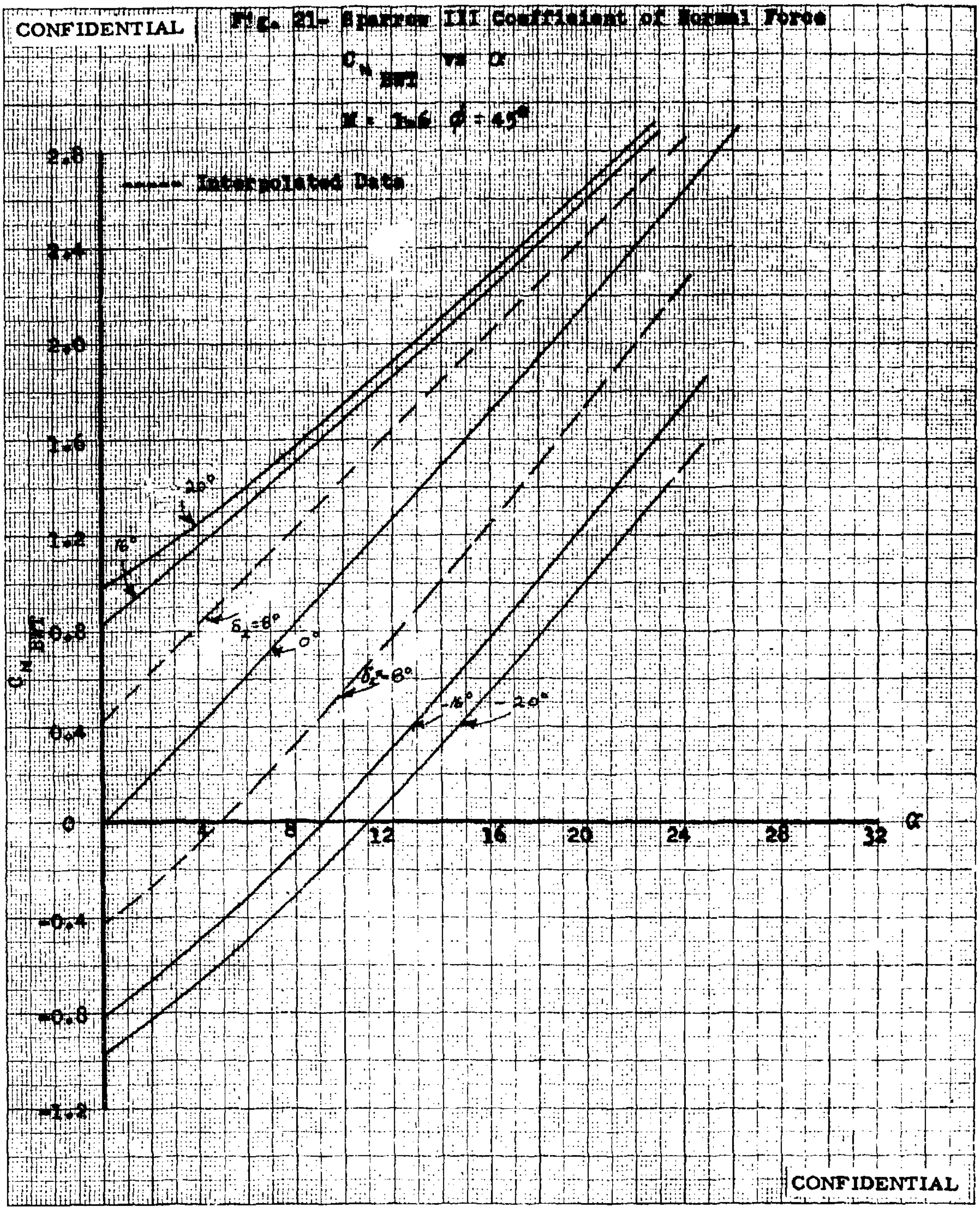

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Fig. 21- Sparrow III Coefficient of Normal Force
$C_{N_{BWT}}$ vs α
M = 1.6 ϕ = 45°
----- Interpolated Data
20°
16°
δ_2=8°
0°
δ_2=-8°
-16°
-20°
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
4
8
12
16
20
24
28
32
α
$C_{N_{BWT}}$
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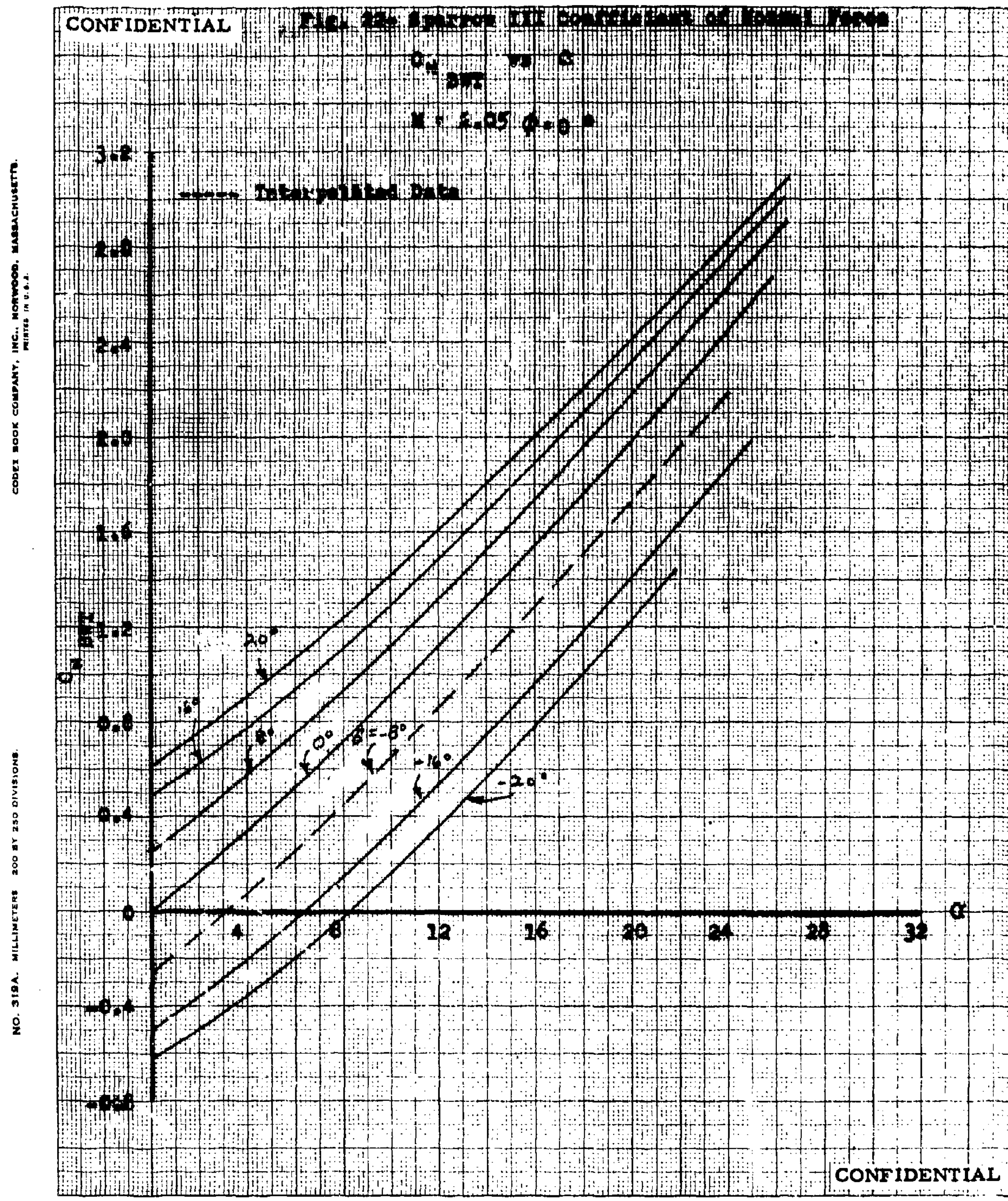
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Interpolated Data
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
-0.4
4
8
12
16
20
24
28
32
α
20°
16°
8°
0°
β = -8°
-16°
-20°
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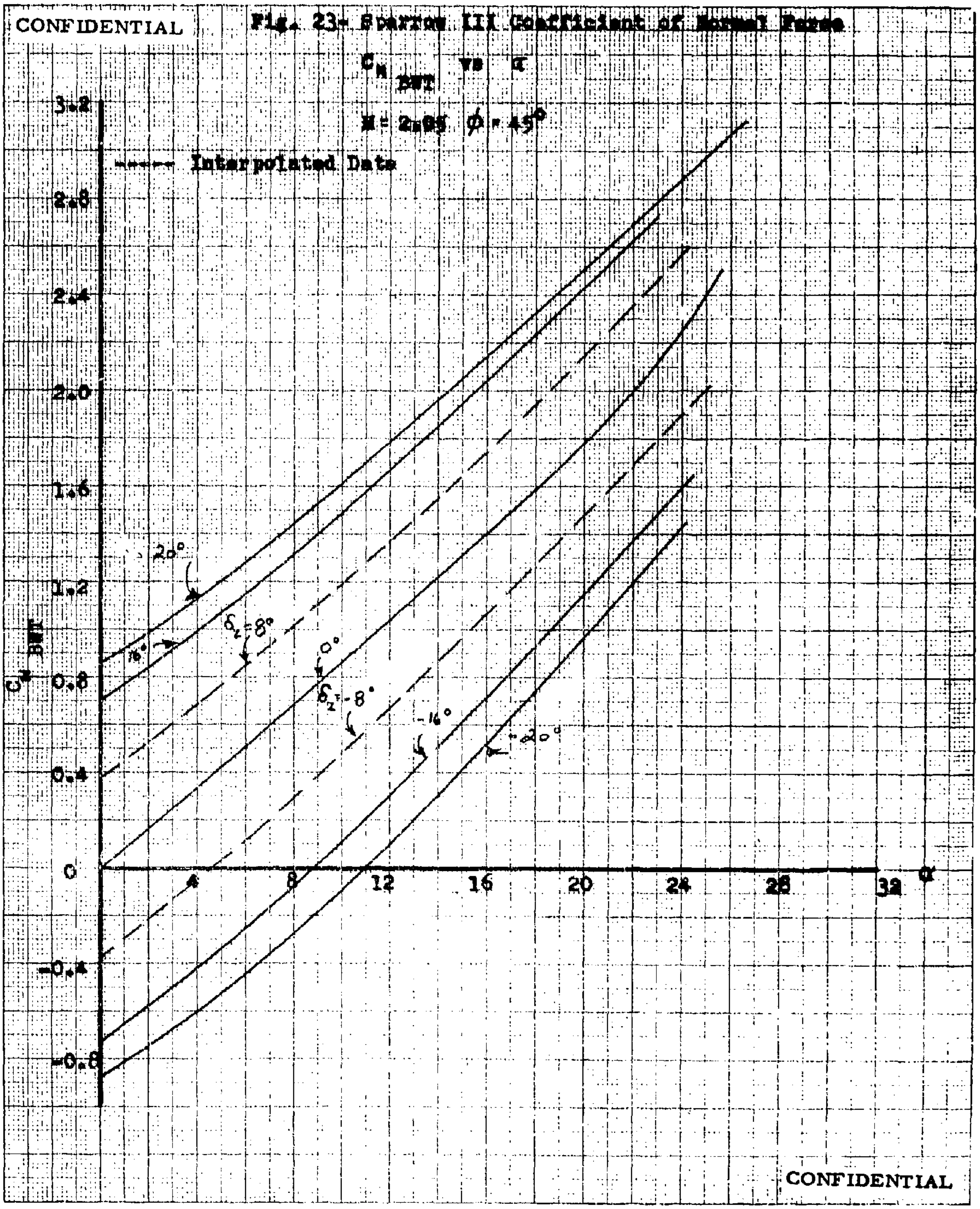

Fig. 23- Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

$M = 2.05$ $\phi = 45^{\circ}$

Fig. 24- Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

M = 2.5 $\phi = 0°$

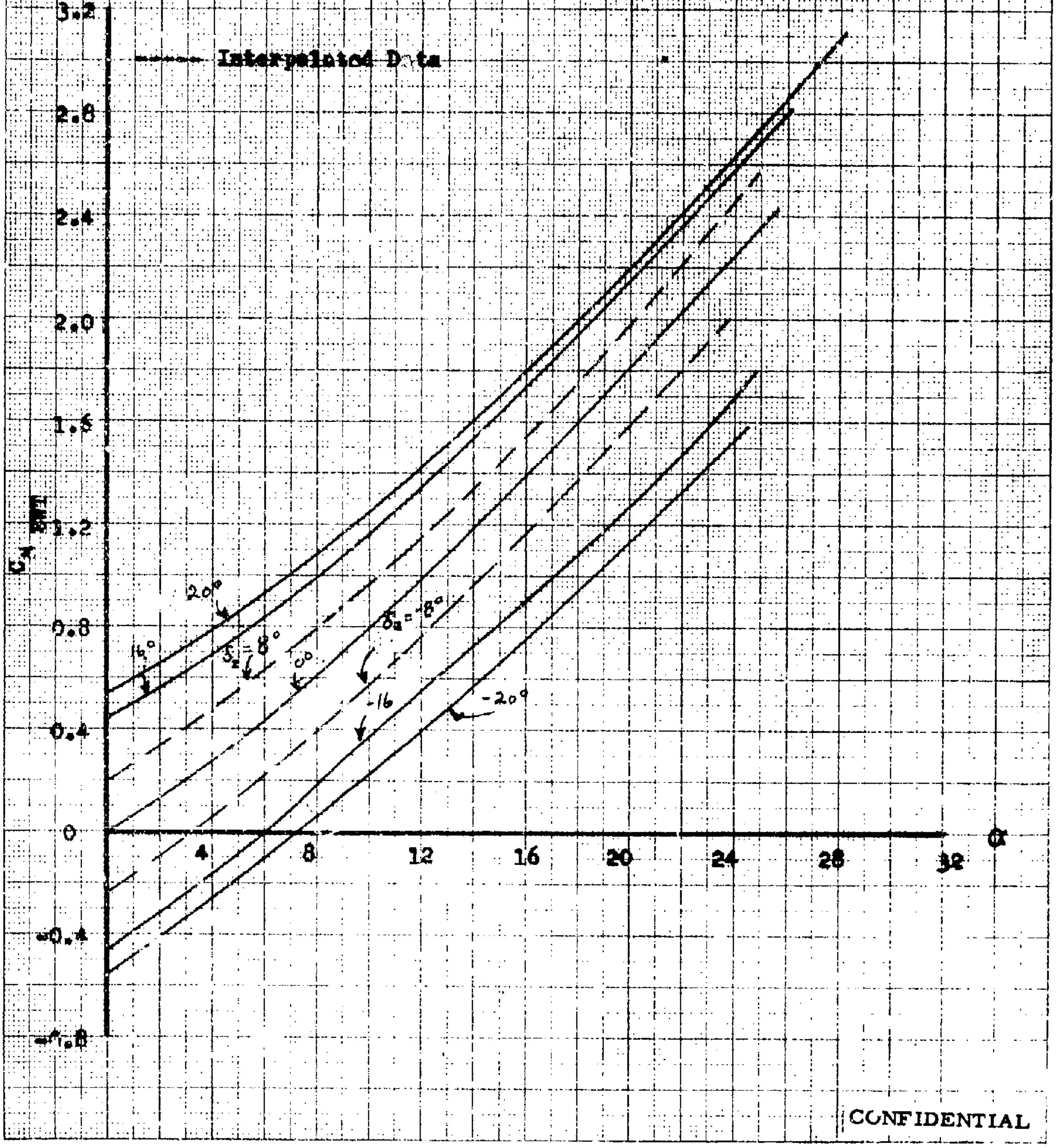

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Fig. 25- Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

$M = 2.58$ $\phi = 45^{\circ}$

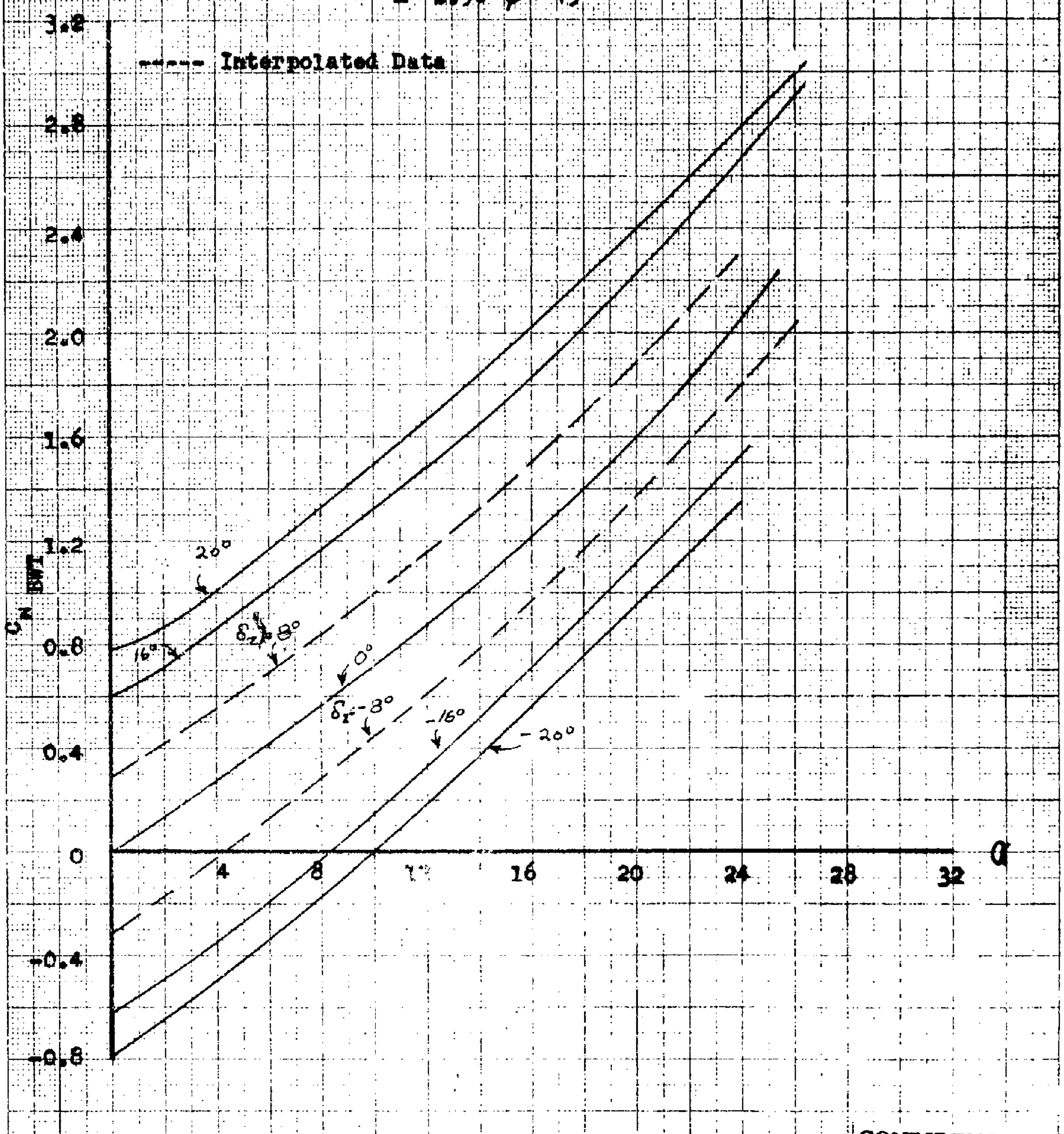

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Fig. 26- Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

M = 3.06 ϕ = 0°

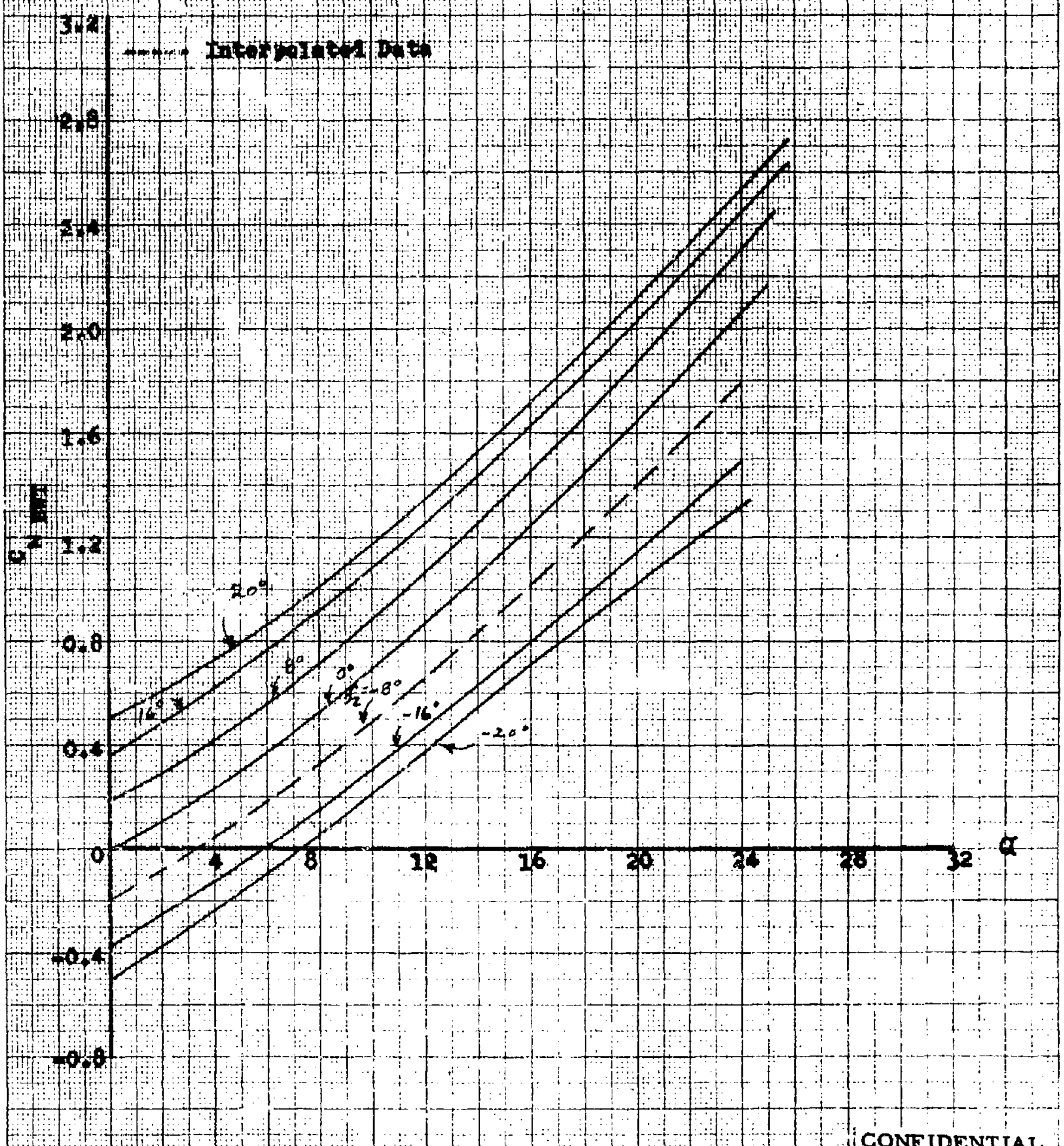

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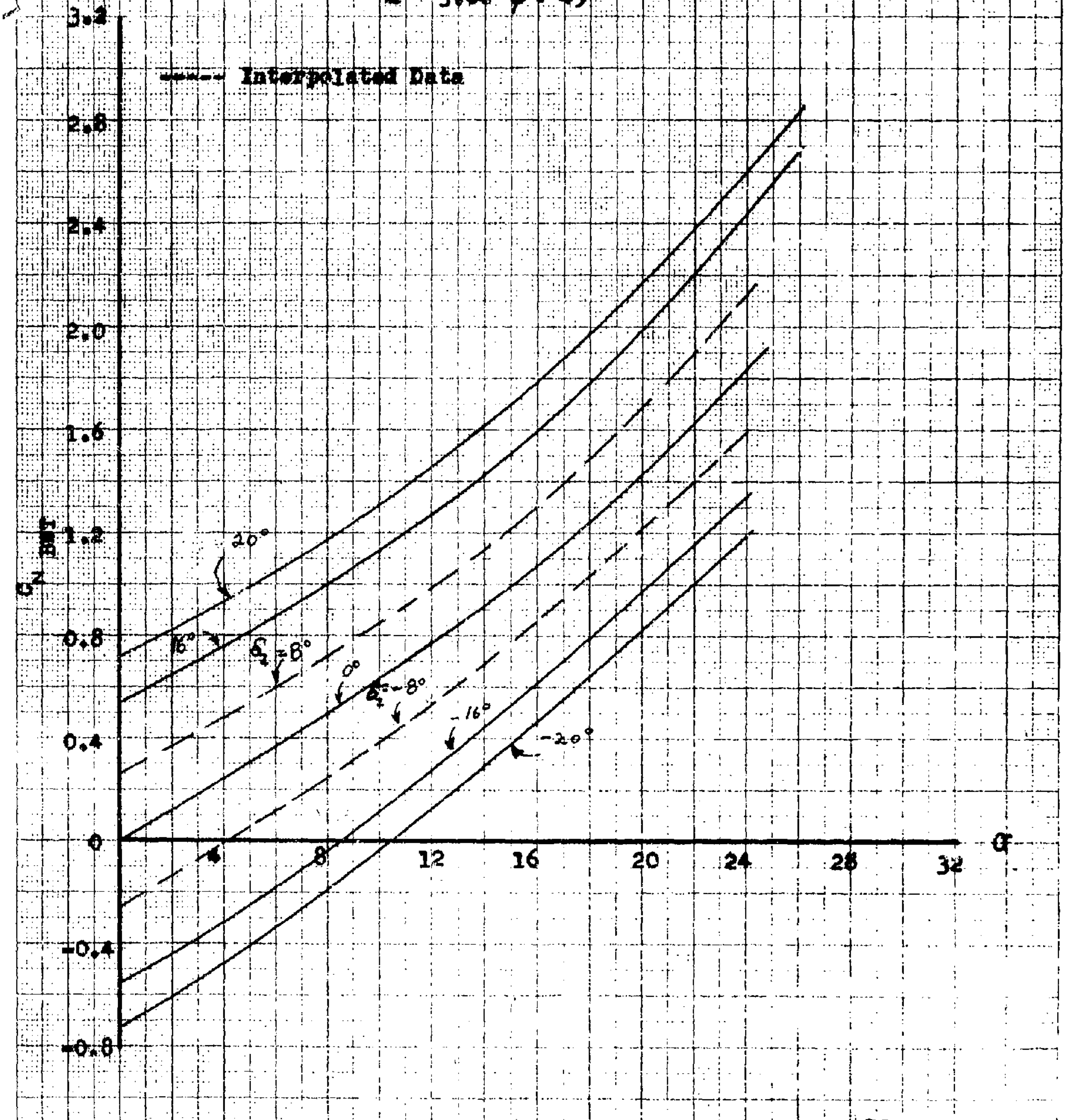
Fig. 27- Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

$M = 3.06 \quad \phi = 45°$



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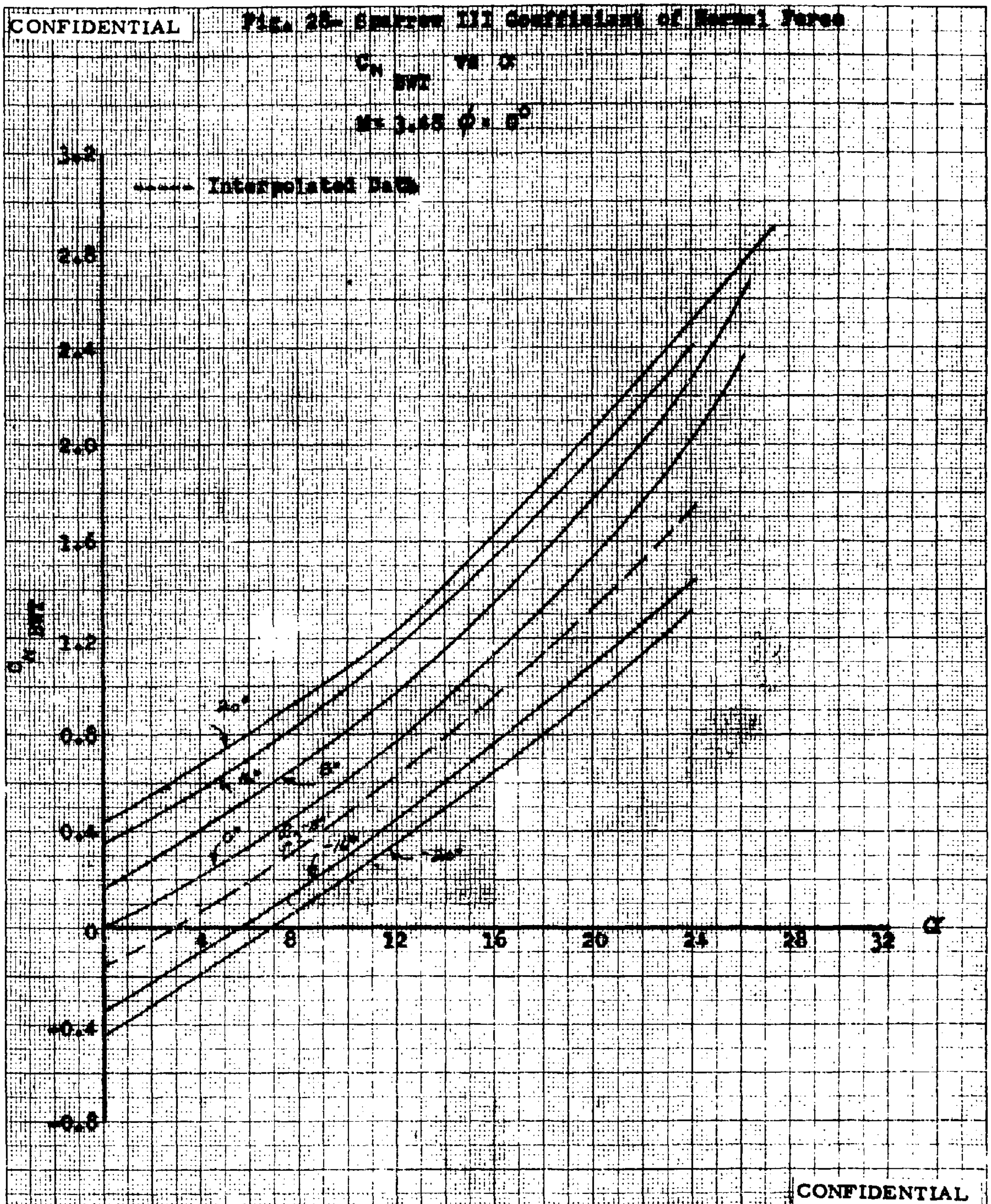

Fig. 28- Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

$M = 3.45$ $\phi = 5°$

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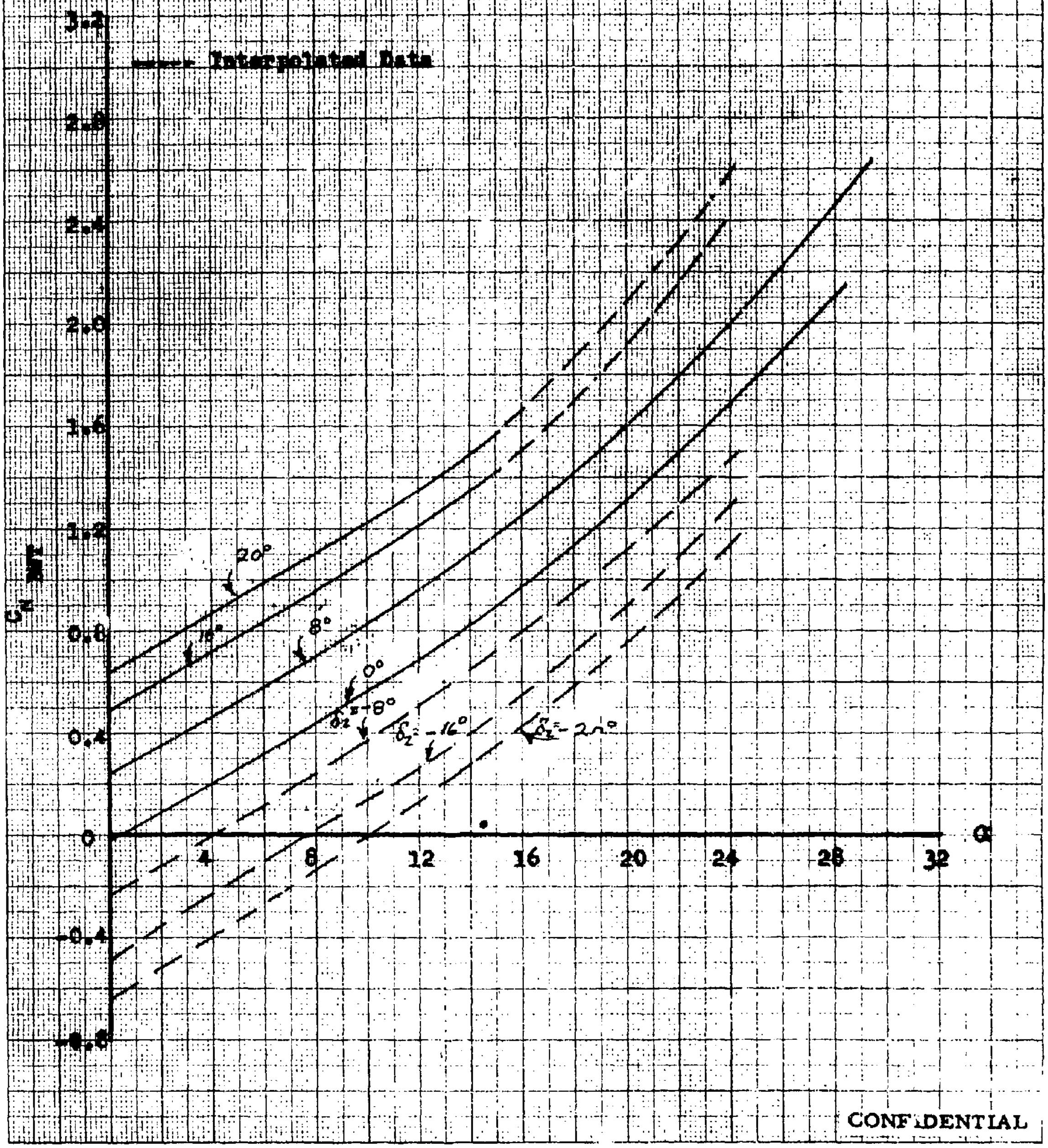
Fig. 29 Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

M = 3.48 ϕ = 45°



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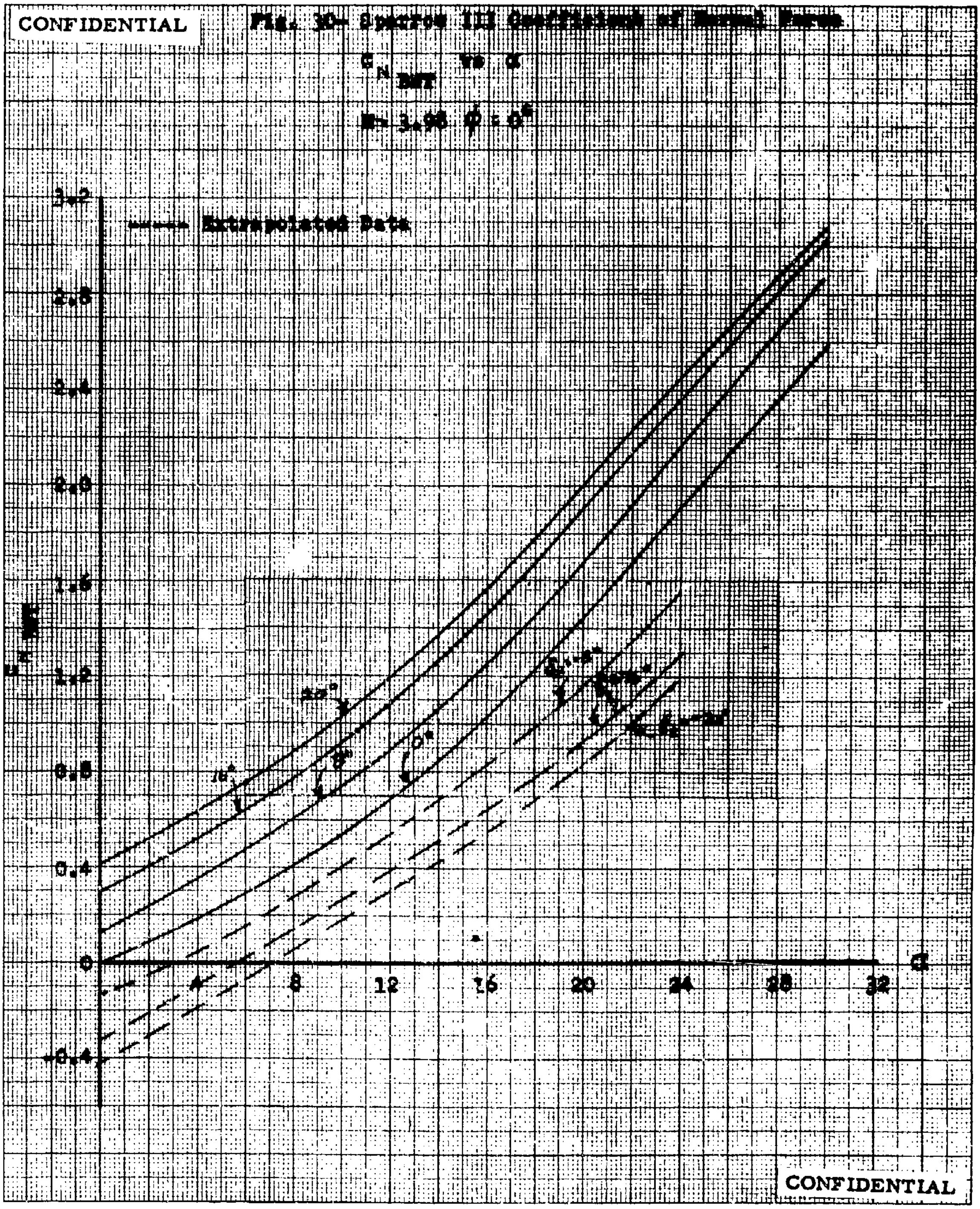
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Fig. 30- Sparrow III Coefficient of Normal Force
$C_{N_{BMT}}$ vs α
M= 3.96 φ = 0°
Extrapolated Data
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
-0.4
4
8
12
16
20
24
28
32
α
10°
20°
8°
0°
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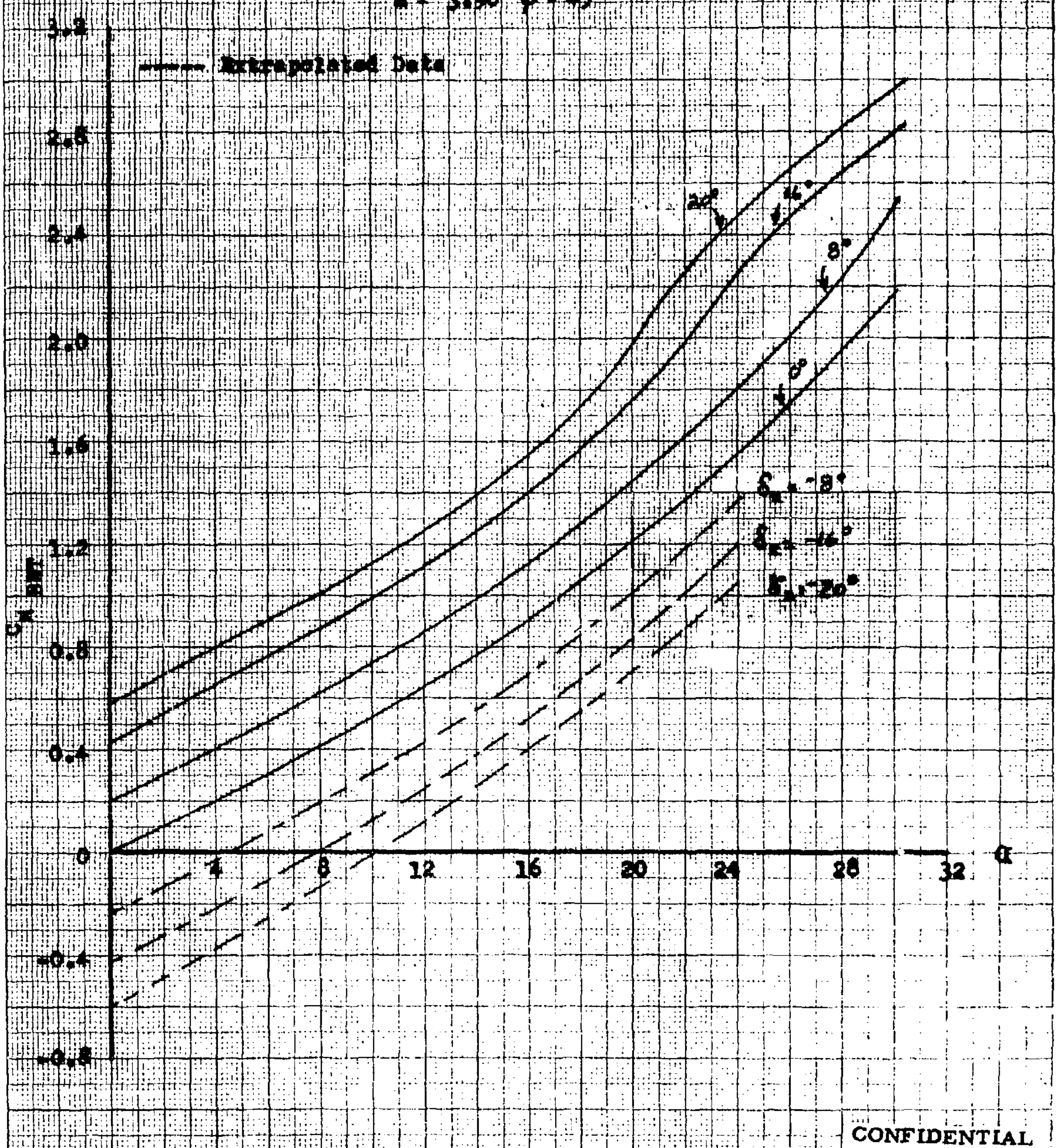
Fig. 31- Sparrow III Coefficient of Normal Force

$C_{N_{BWT}}$ vs α

M = 3.98 ϕ = 45°



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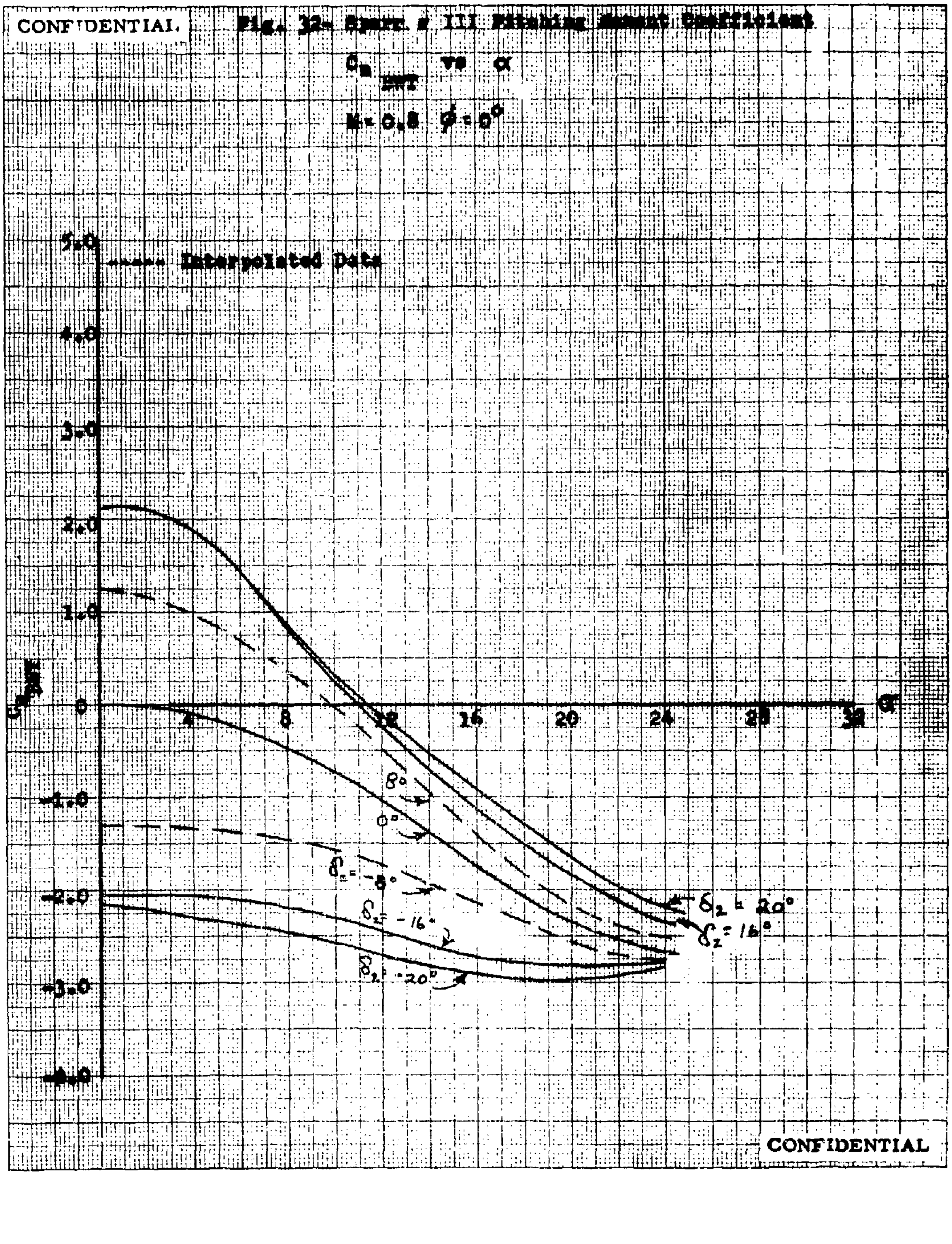

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Fig. 33- Sparrow III Pitching Moment Coefficient

$C_{m_{BWT}}$ vs α

$M = 0.8$ $\phi = 45°$

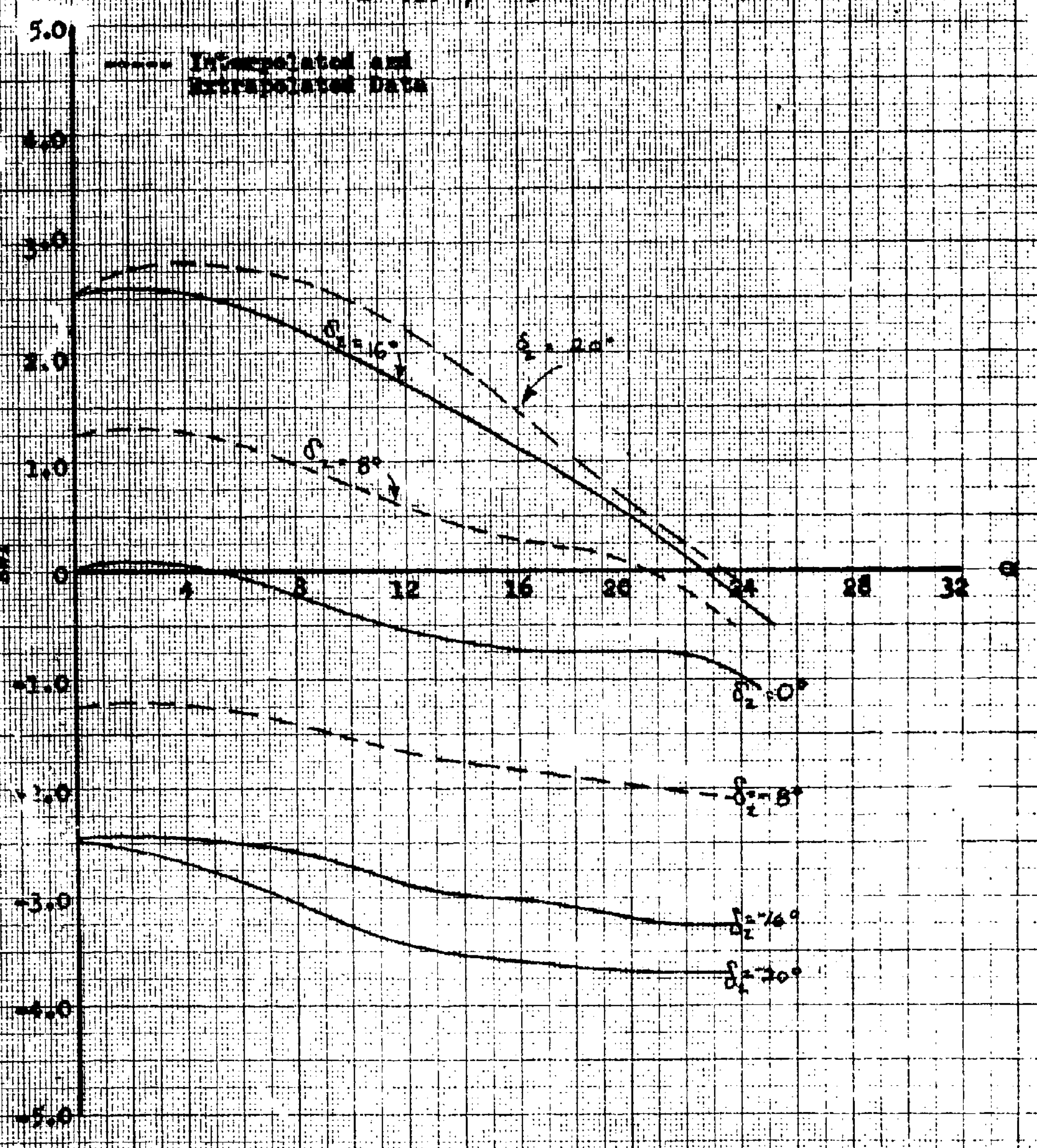

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Fig. 34- Sparrow III Pitching Moment Coefficient

$C_{m_{BWT}}$ vs α

$M = 1.0$ $\phi = 0^\circ$

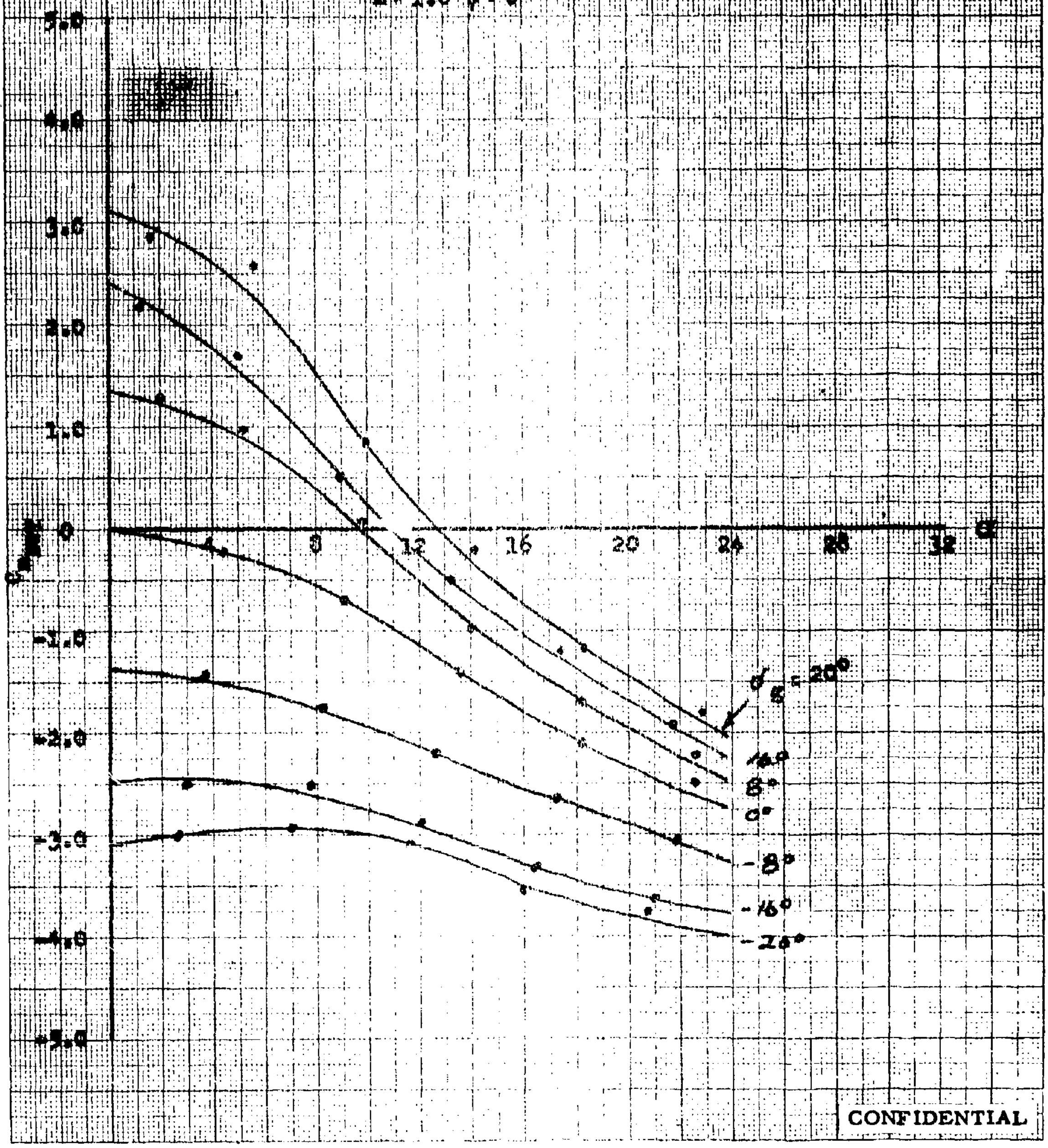

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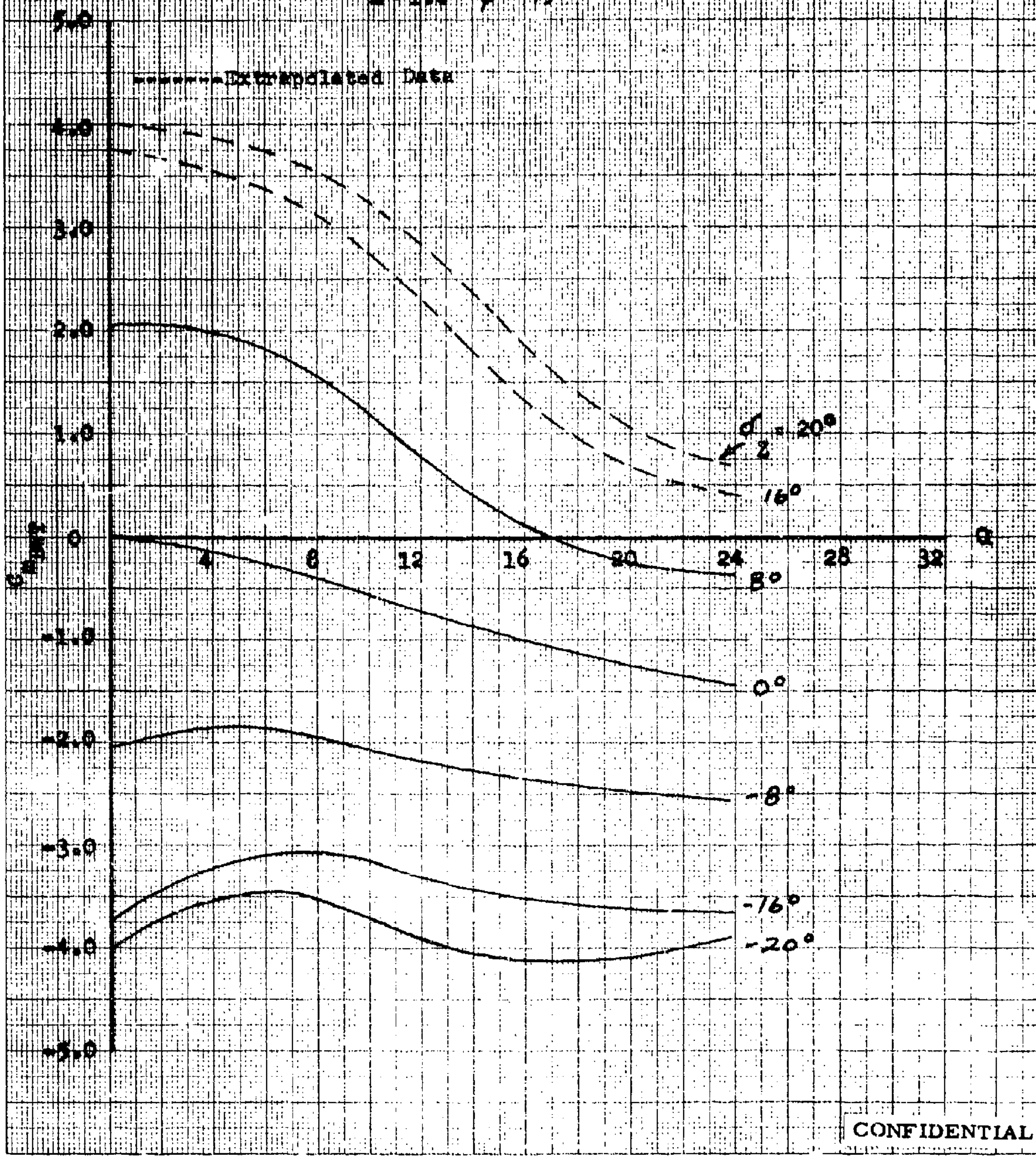
Fig. 35- Sparrow III Pitching Moment Coefficient

$C_{m_{BMF}}$ vs α

M = 1.0 ϕ = 45°



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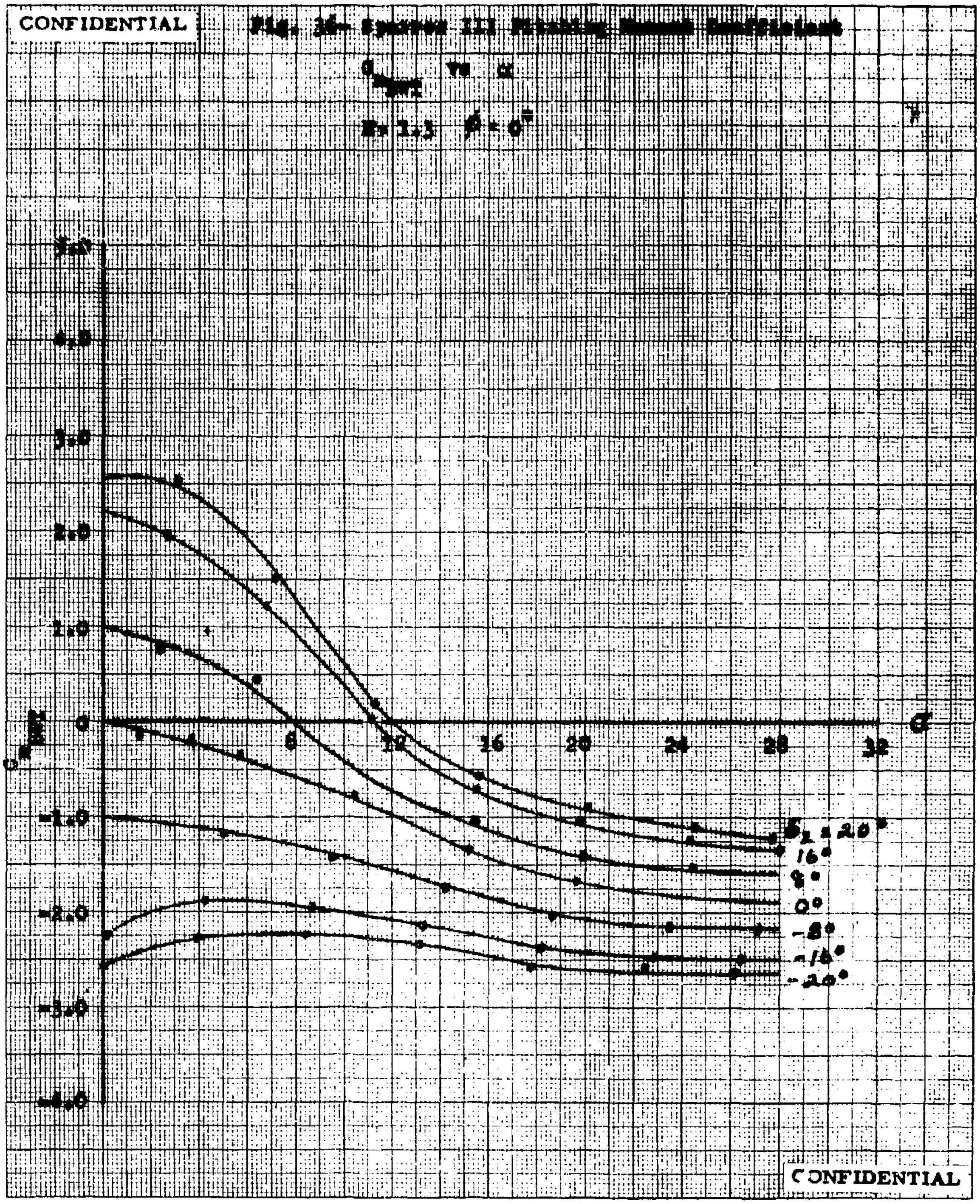
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3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
16
20
24
28
32
$\delta_1 = 20°$
16°
0°
-8°
-16°
-20°
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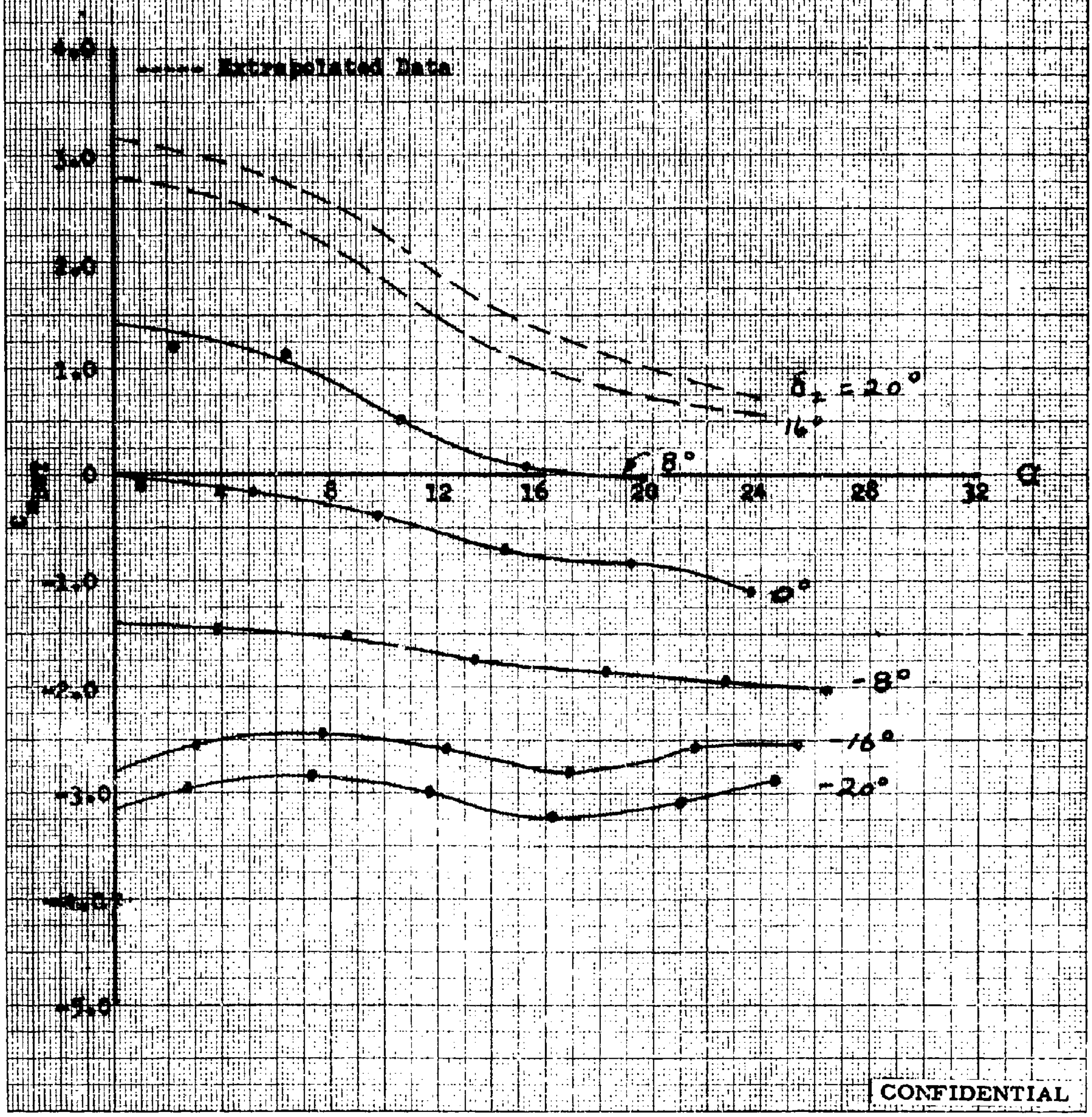
Fig. 37- Sparrow III Pitching Moment Coefficient

$C_{m_{BWT}}$ vs α

$M = 1.3 \quad \phi = 45^\circ$



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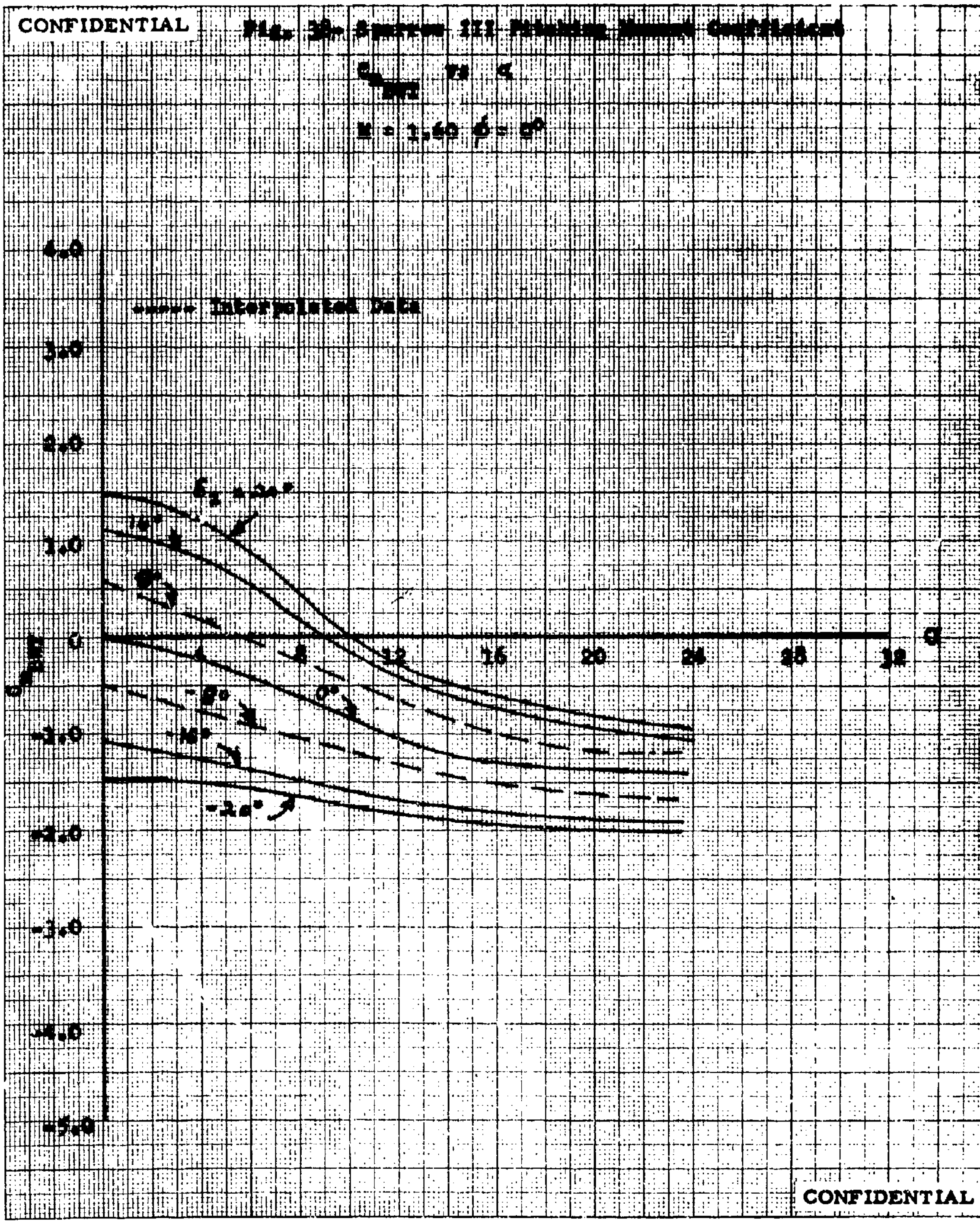

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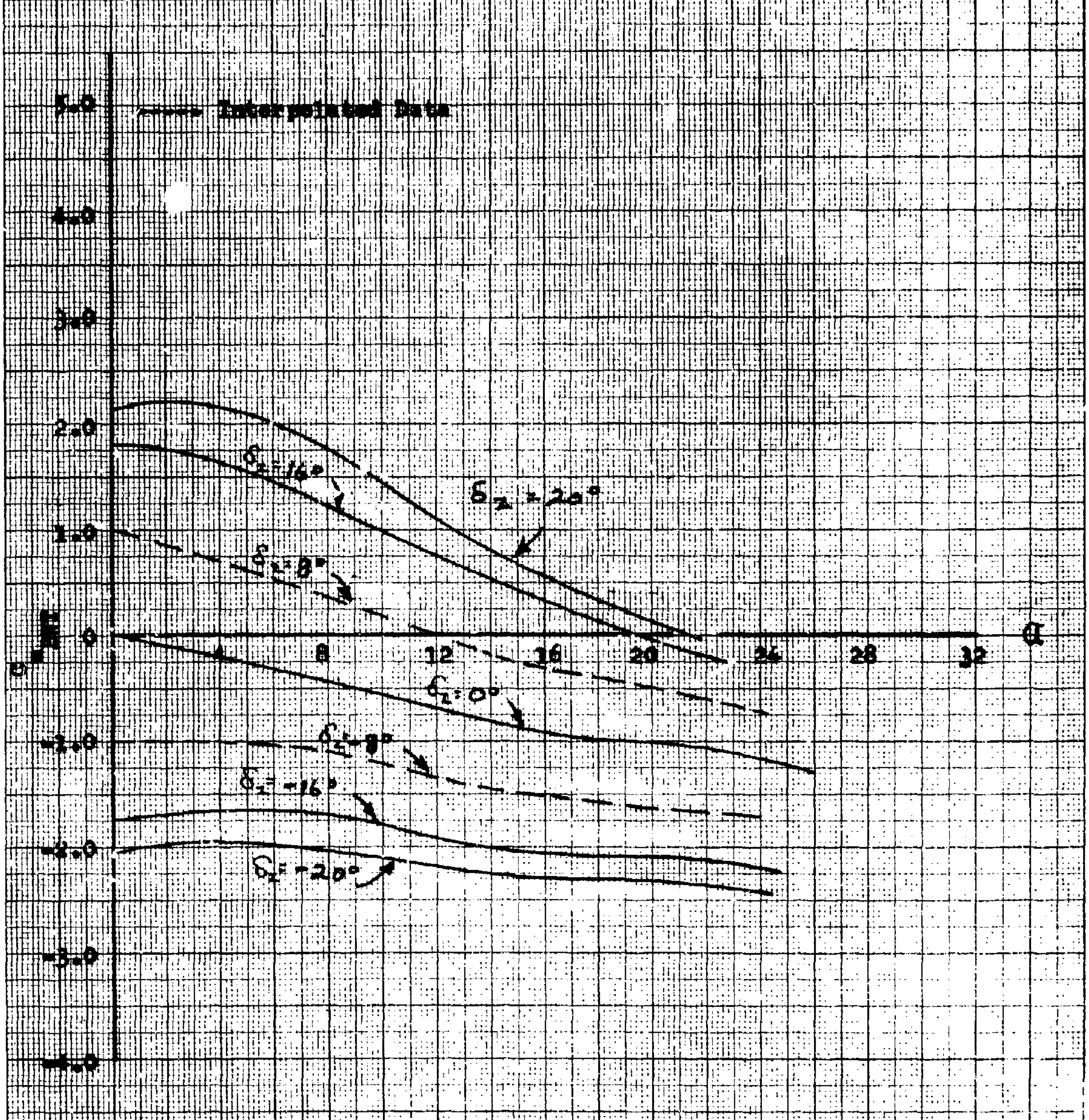
Fig. 35- Sparrow III Pitching Moment Coefficient

$C_{m_{BMT}}$ vs α

M = 1.60 ϕ = 45°



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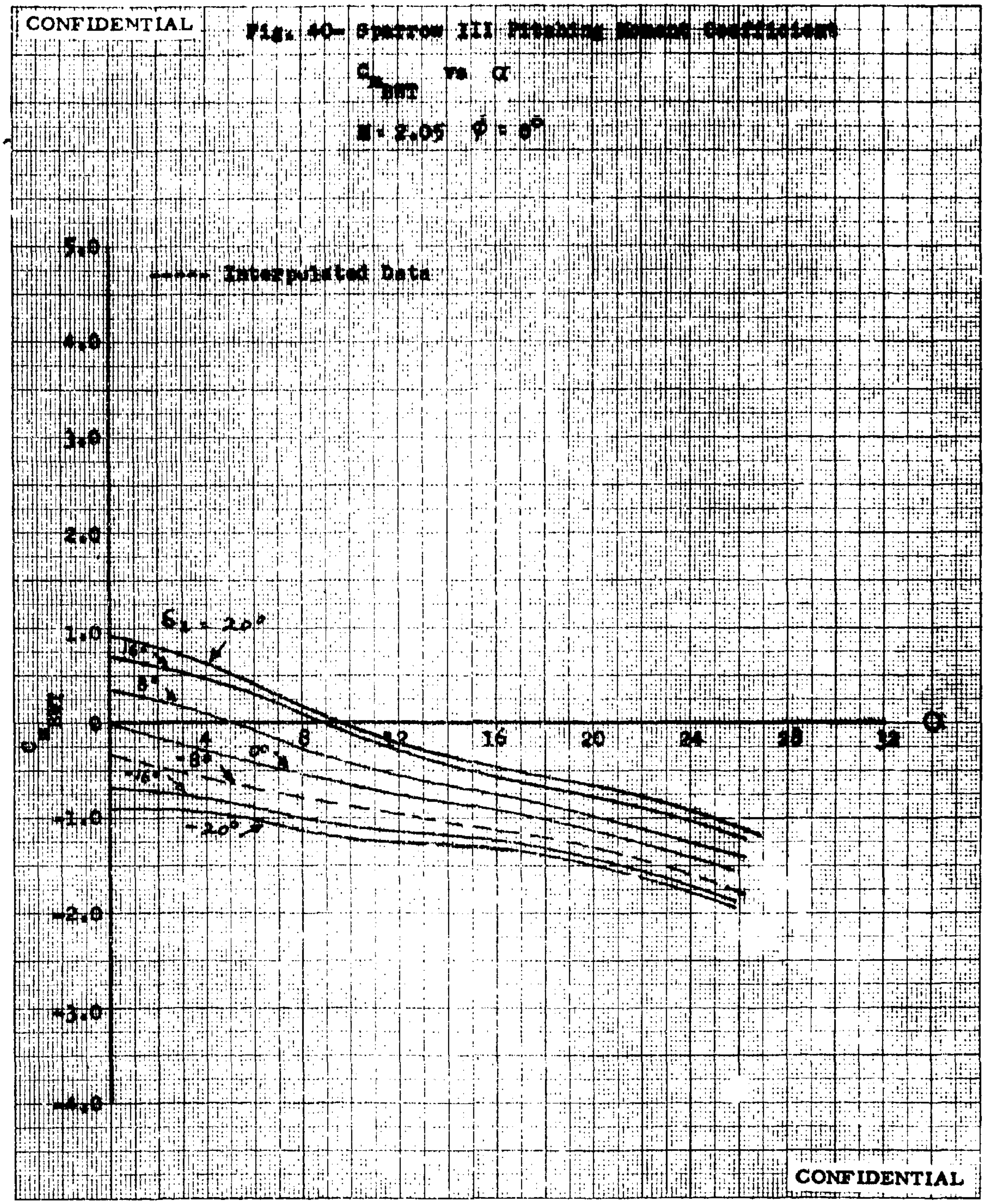

Fig. 40- Sparrow III Pitching Moment Coefficient

$C_{m_{BST}}$ vs α

$M = 2.05$ $\phi = 0°$

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Fig. 41- Sparrow III Pitching Moment Coefficient

C_{m} vs α

M = 2.05 ϕ = 45°

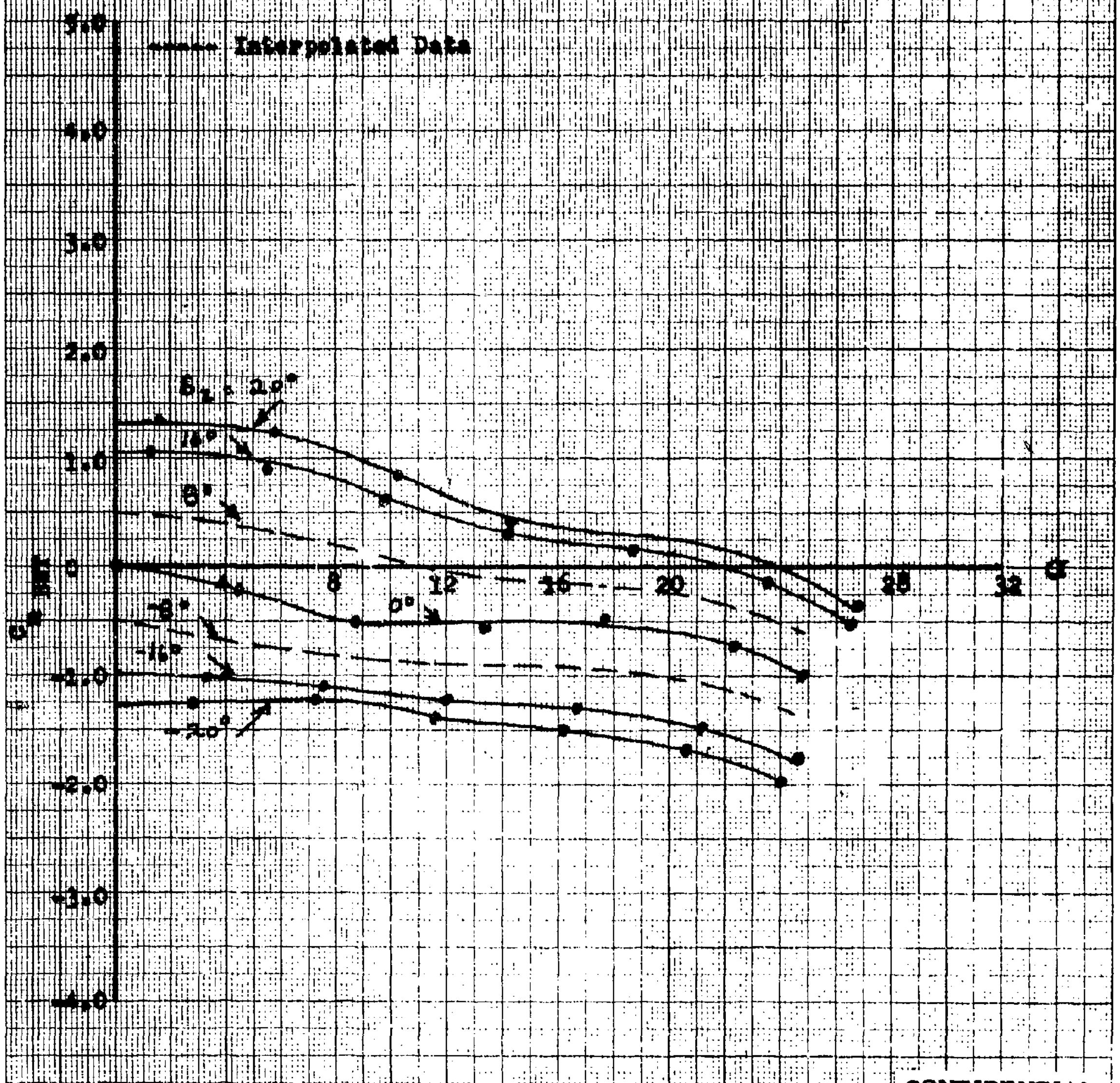

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Fig. 42m Sparrow III Pitching Moment Coefficient

$C_{m_{BCT}}$ vs α

$M = 2.58$ $\phi = 0°$

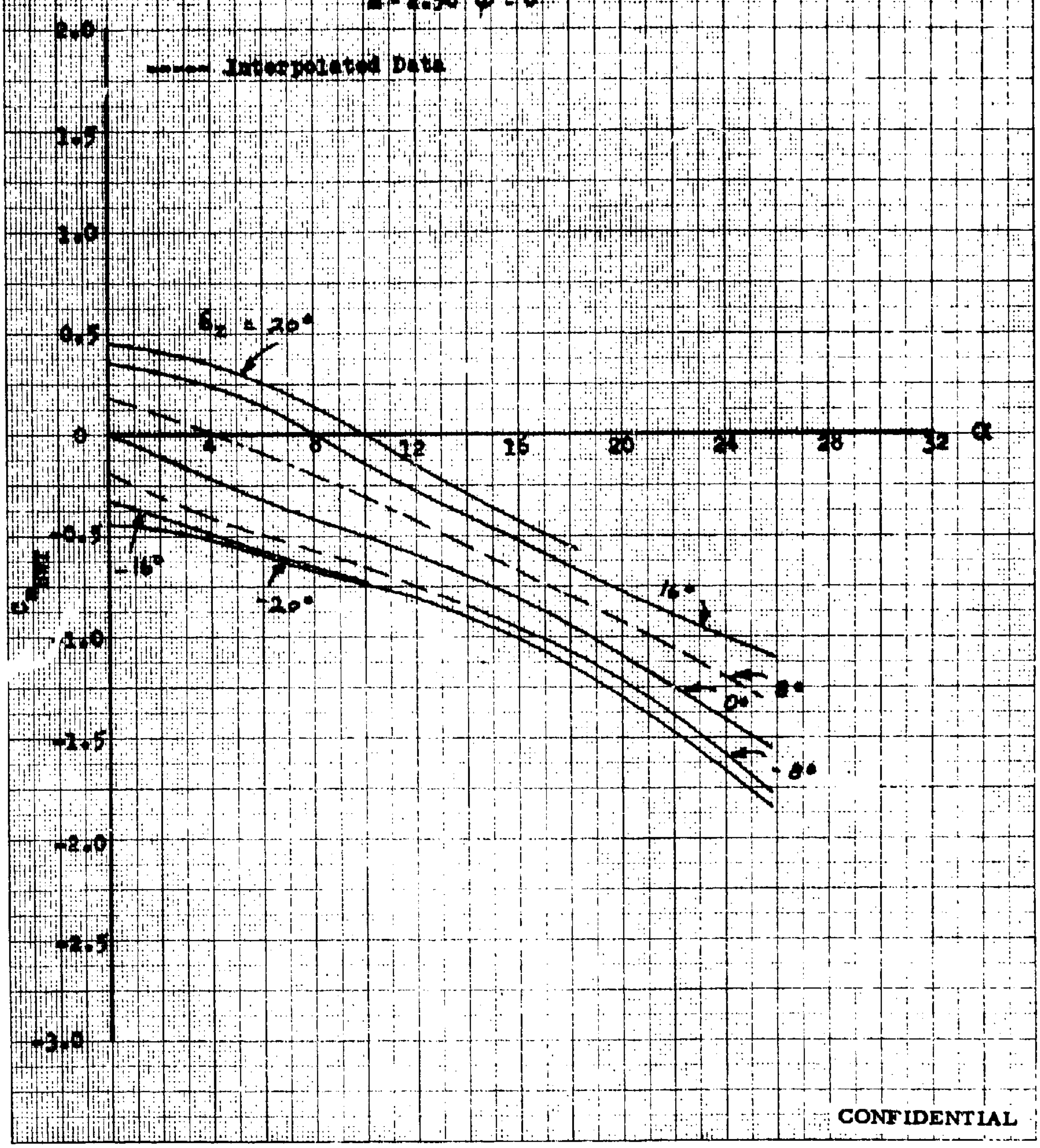

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Fig. 43- Sparrow III Pitching Moment Coefficient

$C_{m_{BWT}}$ vs α

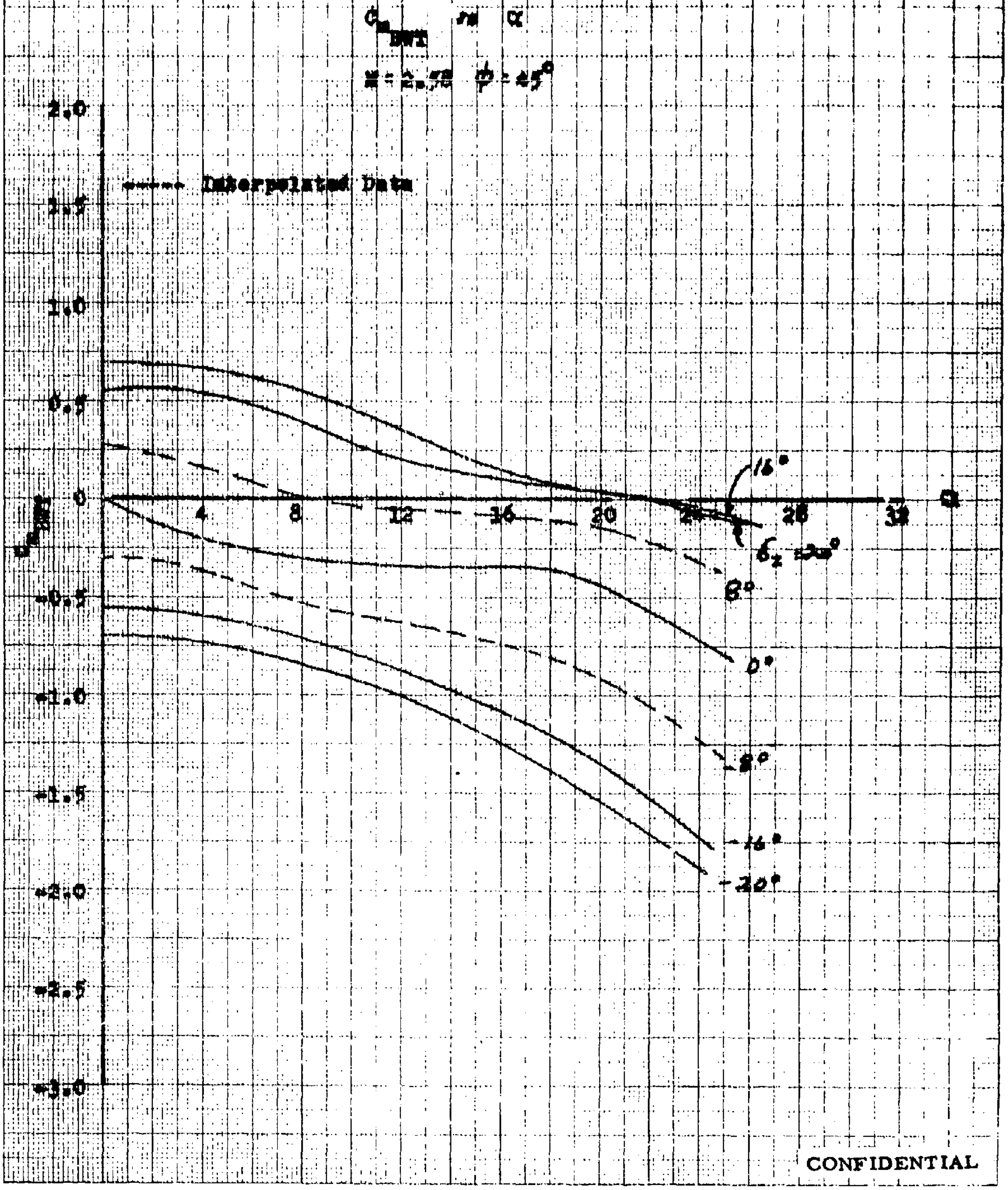

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Fig. 44- Sparrow III Pitching Moment Coefficient

$C_{m_{BWT}}$ vs α

$M = 3.06$ $\phi = 0°$

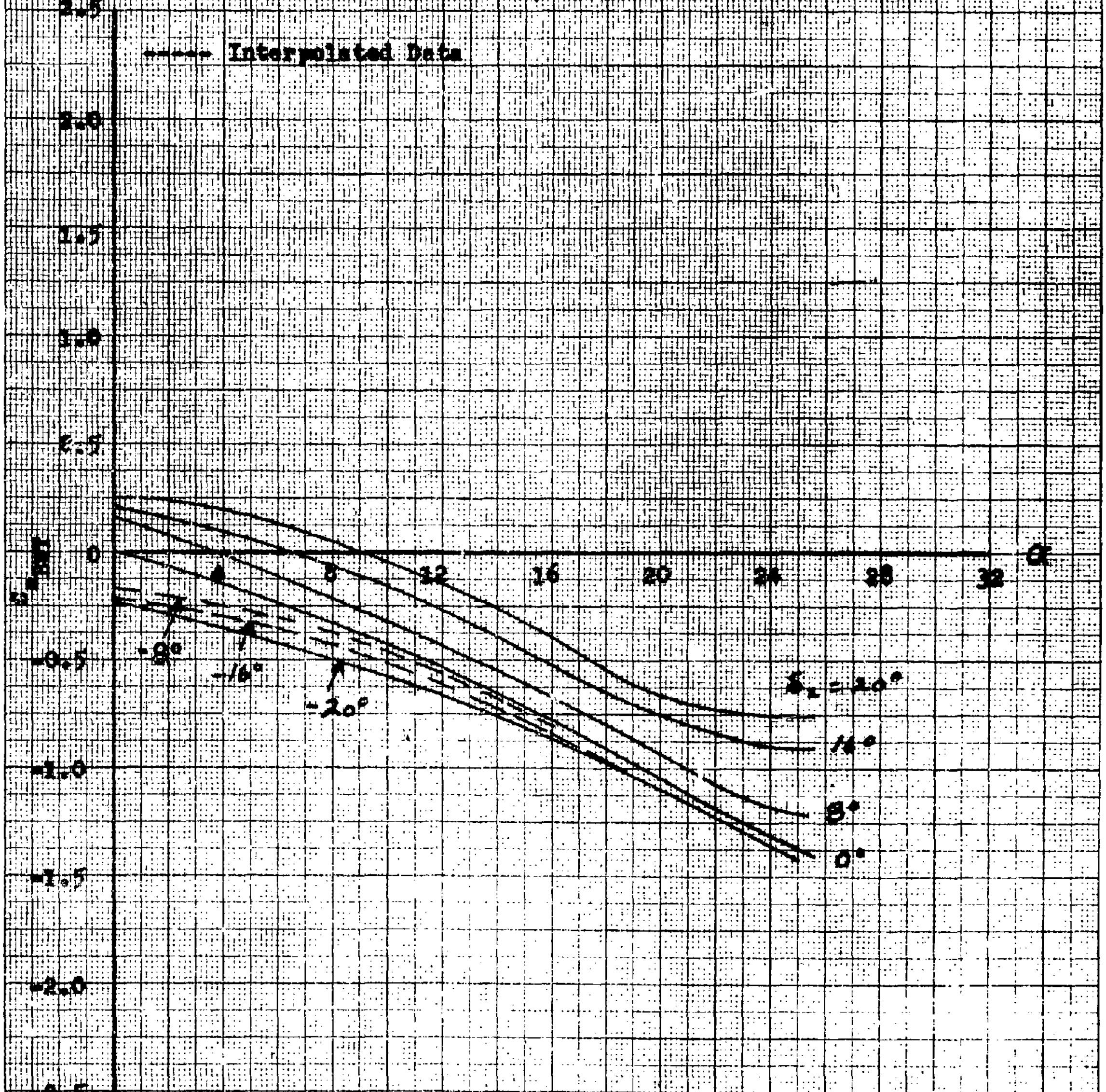

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Fig. 45- Sparrow III Pitching Moment Coefficient

$C_{m_{BMT}}$ vs α

M = 3.06 ϕ = 45°

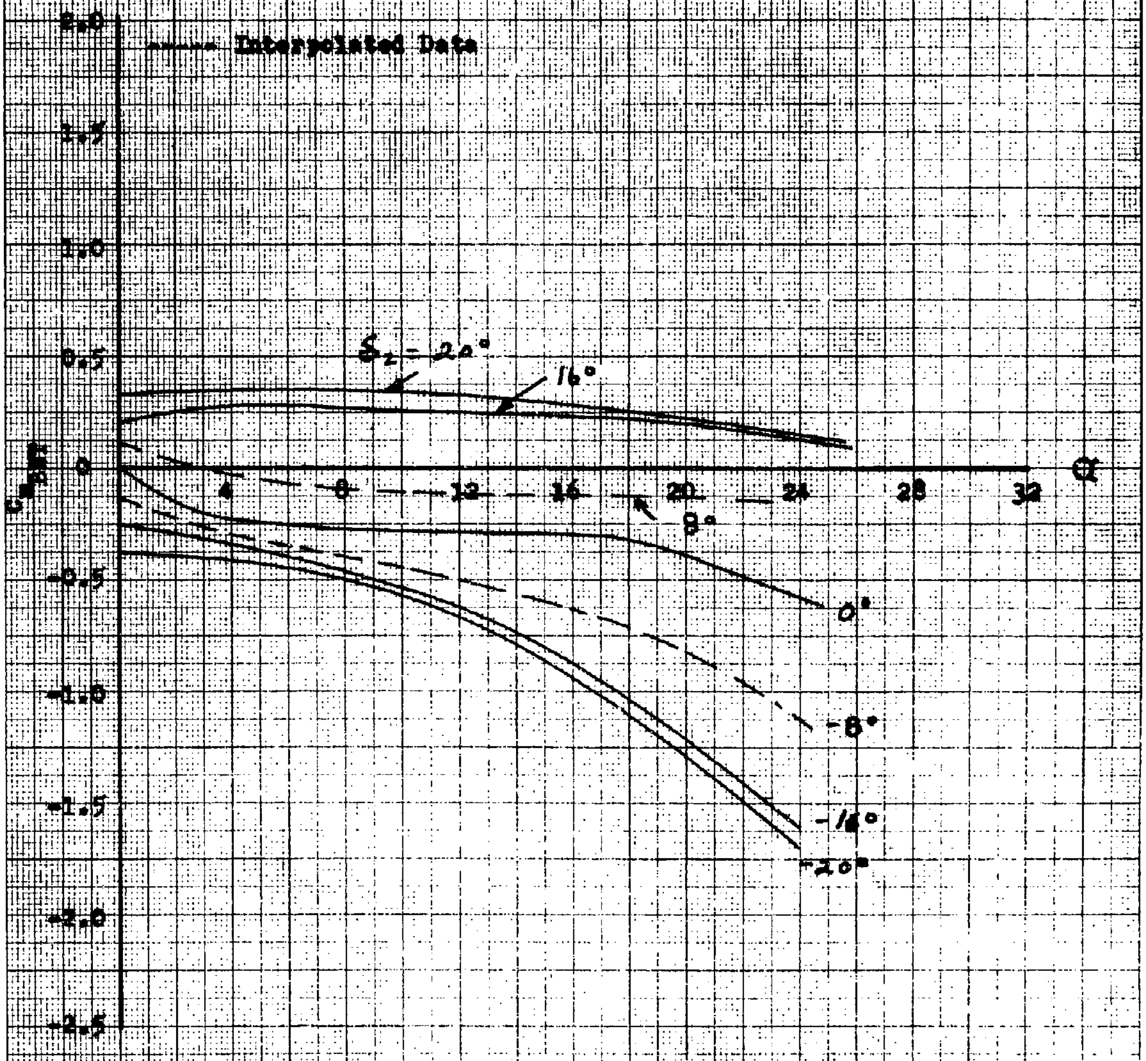
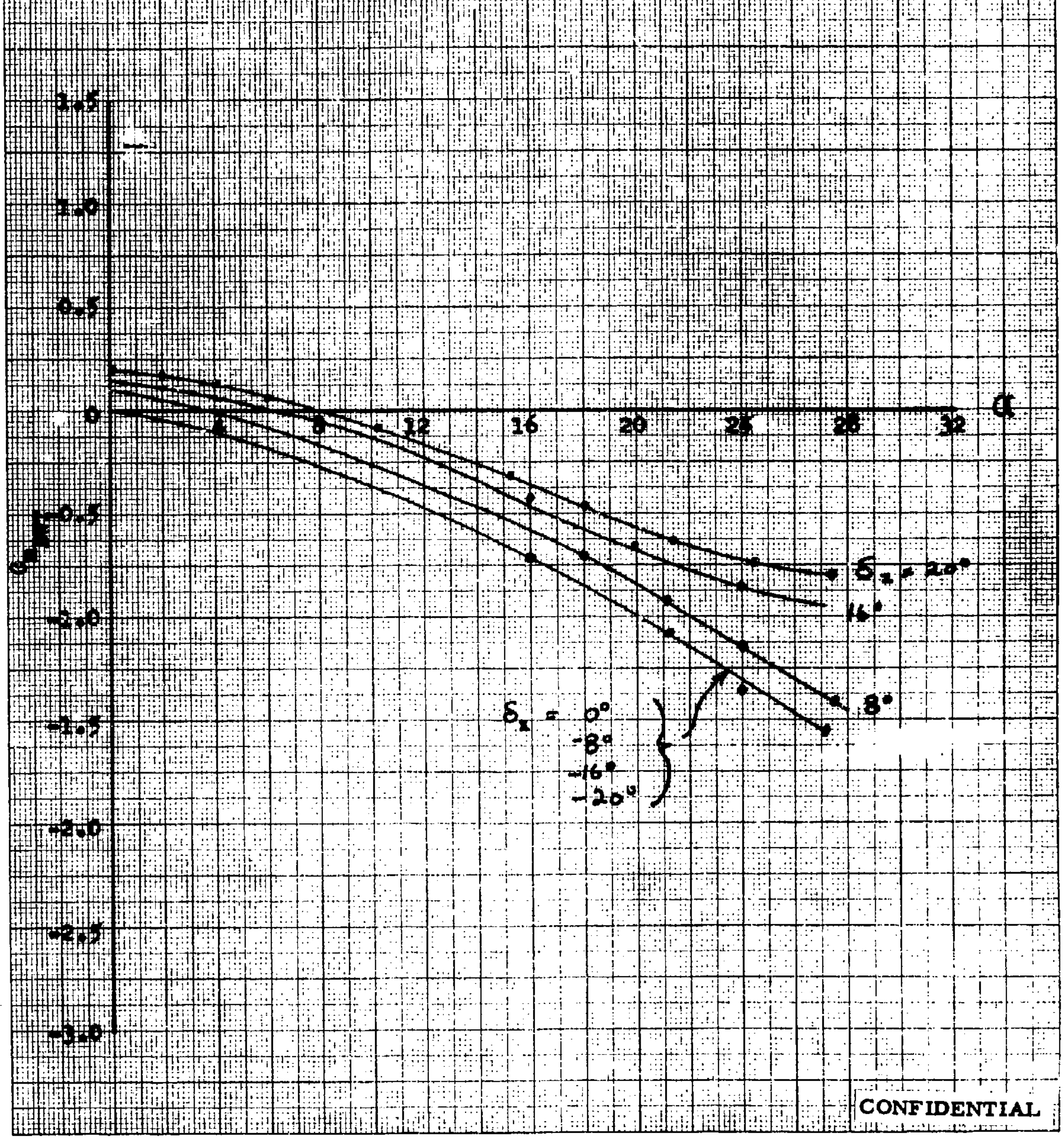
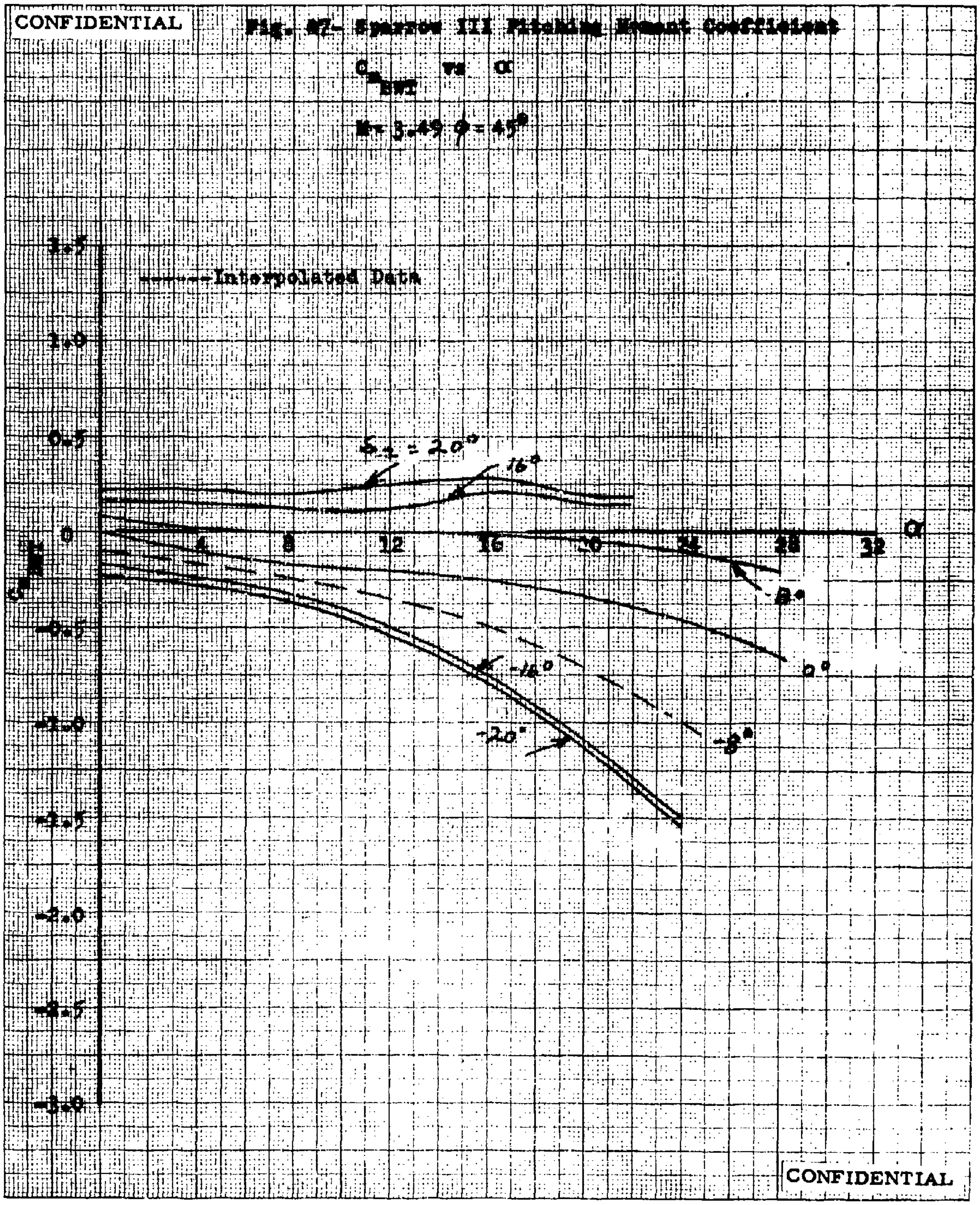


Fig. 46– Sparrow III Pitching Moment Coefficient

$C_{m_{BET}}$ vs α

$M = 3.49$ $\phi = 0°$





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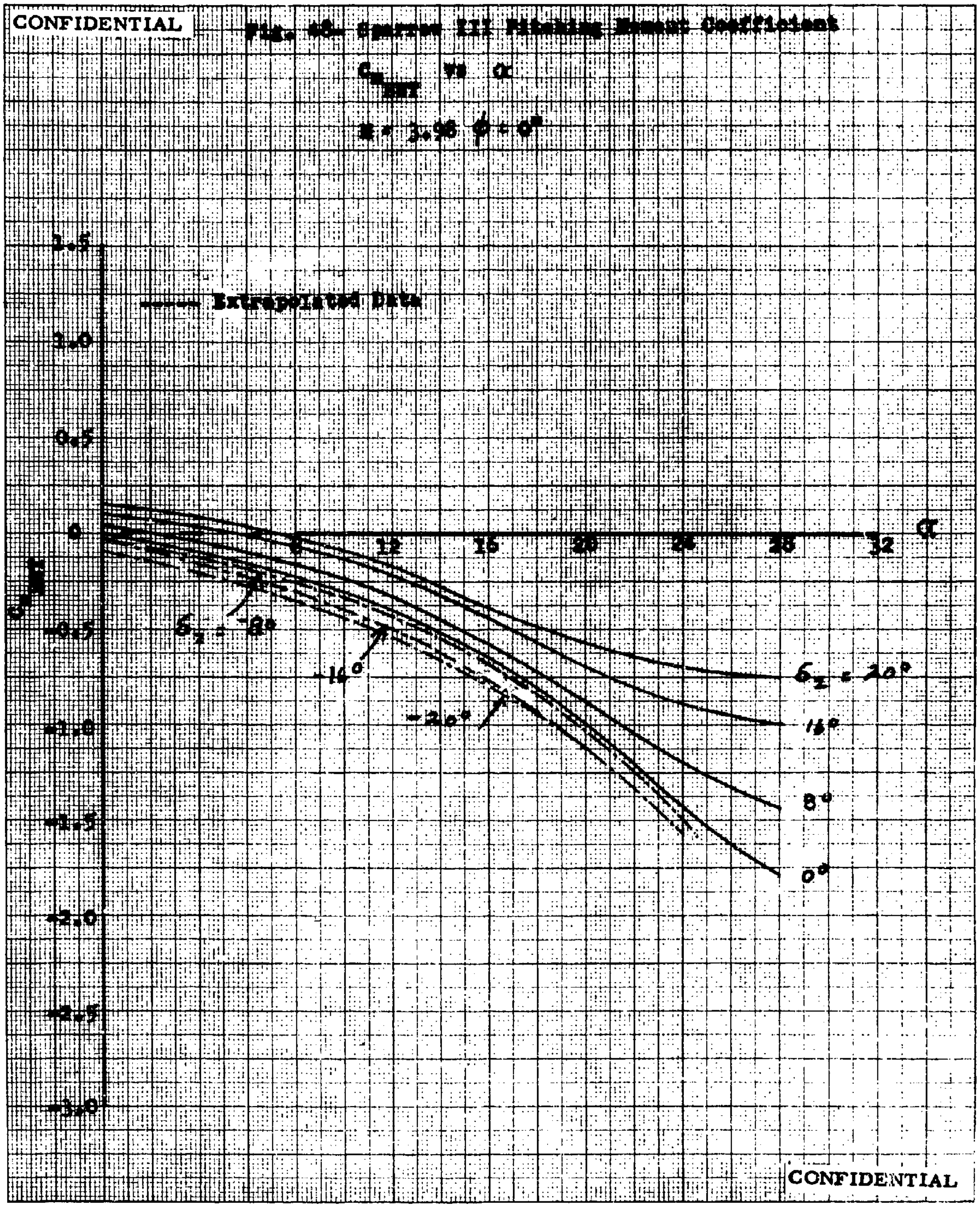
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Sparrow III Pitching Moment Coefficient
vs α
3.95 φ = 0°
Extrapolated Data
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
8
12
16
20
24
28
32
α
δ = -8°
-16°
-20°
δ = 20°
16°
8°
0°
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Fig. 42- Sparrow III Pitching Moment Coefficient

$C_{m_{PRT}}$ vs α

M = 2.96 ϕ = 45°

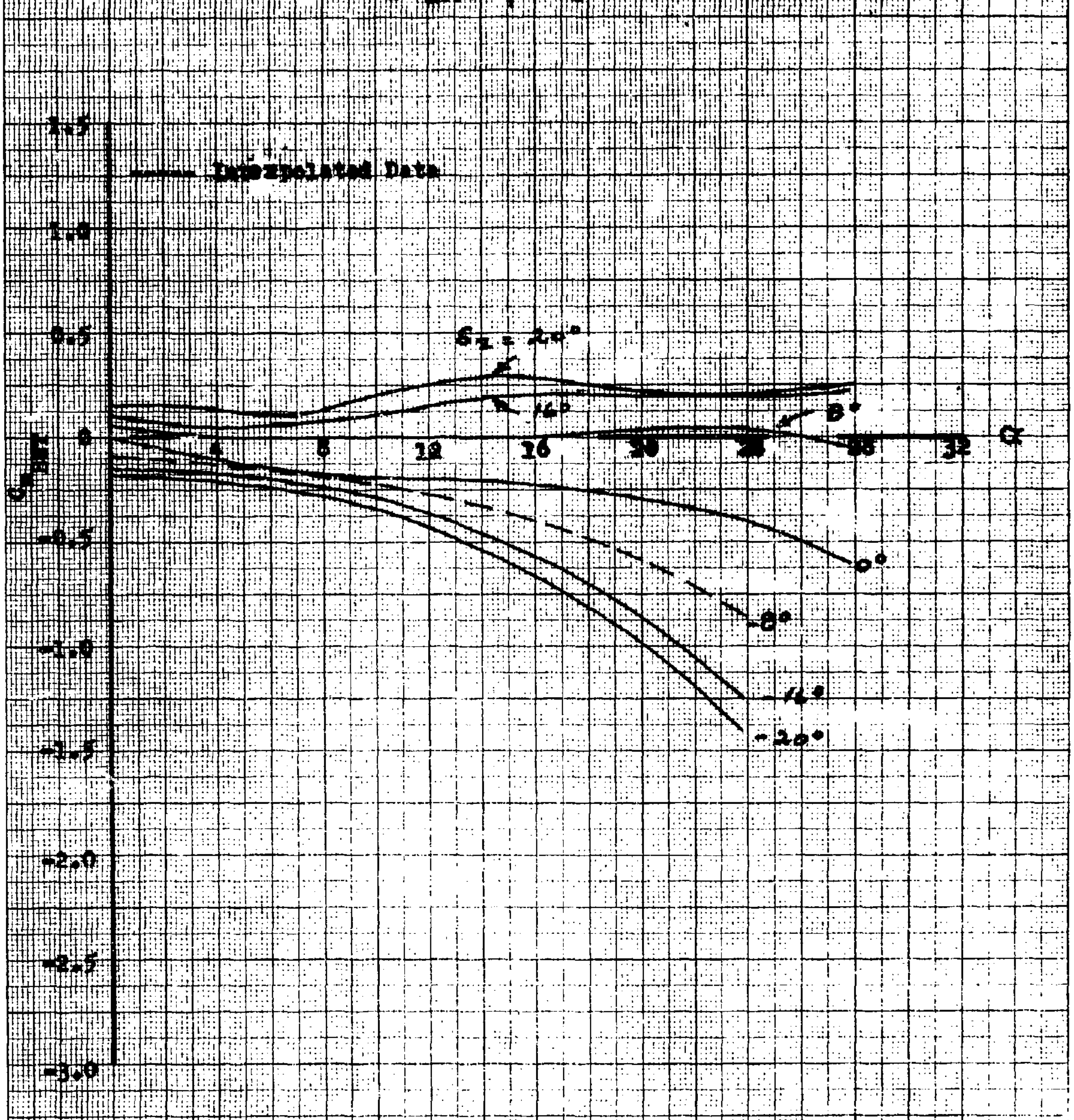

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Fig. 50- Sparrow III Estimated Pitch Derivatives

C_{m_q} vs Mach No.

Rigid Conditions
Altitude = 70,000 Ft.

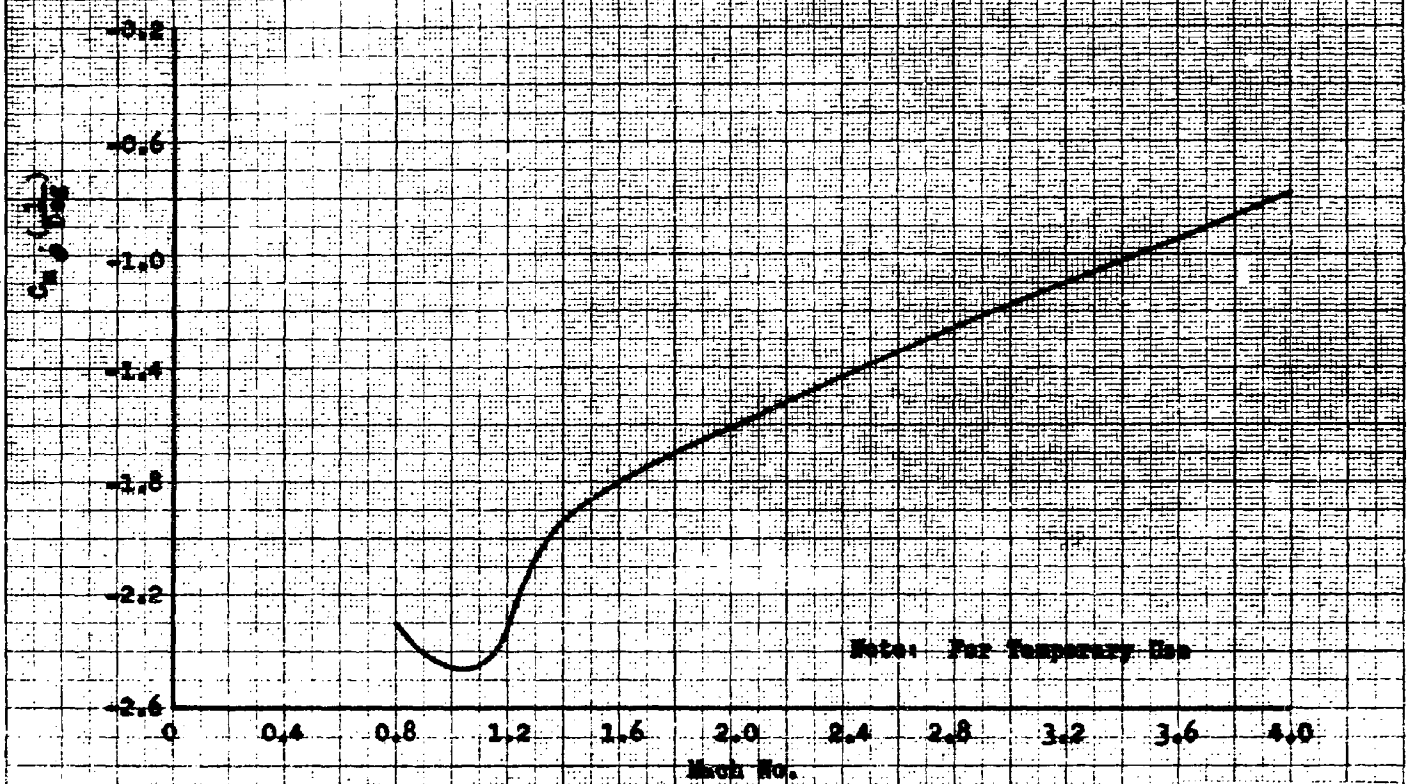

Fig. 51- Sparrow III Estimated Pitch Derivative

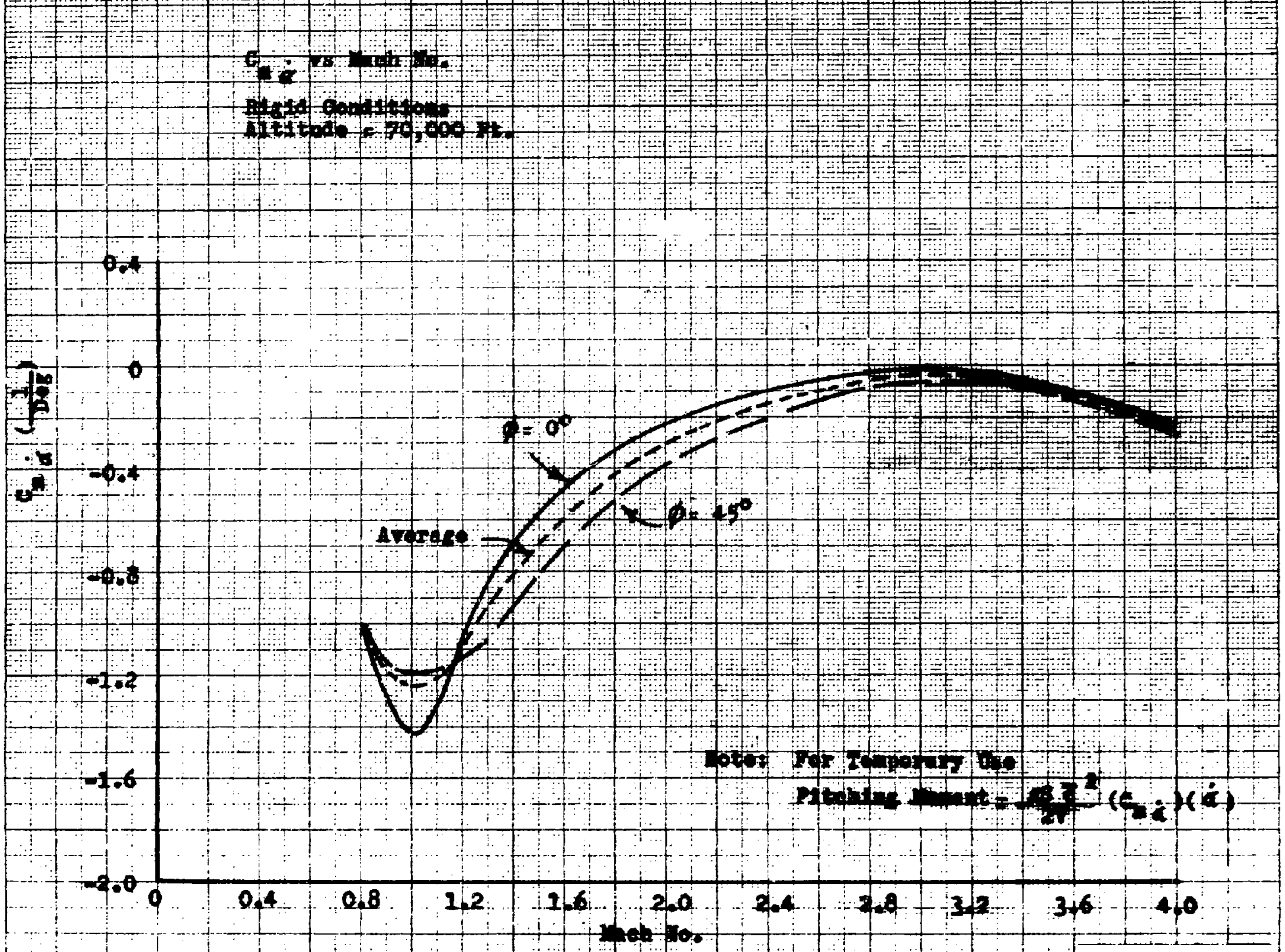

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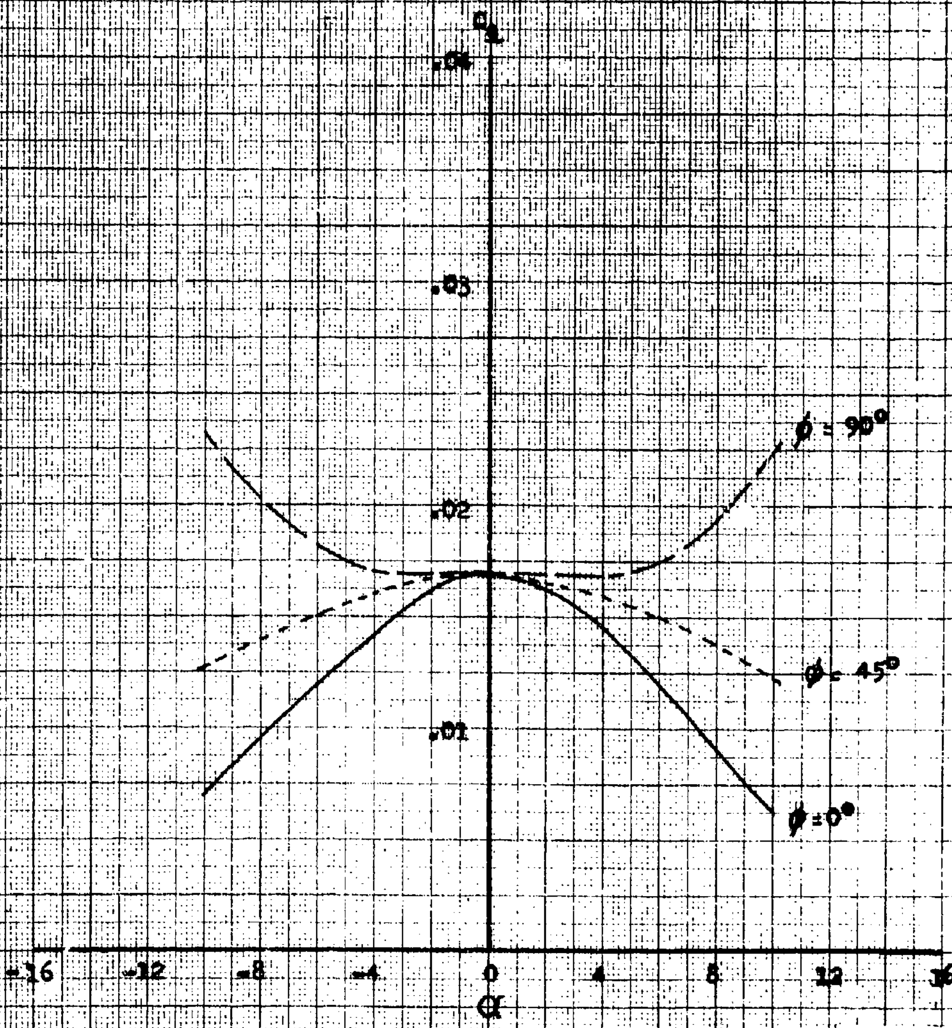
Fig. 52- Sparrow III Estimated Rolling Moment Coefficient

C_l vs α

Mach 0.5 - Altitude = 70,000 Ft.

Rigid Conditions - Configuration WBT

$\delta_y = 0^\circ$ $\delta_z = 0^\circ$ $\delta_x = 0^\circ$



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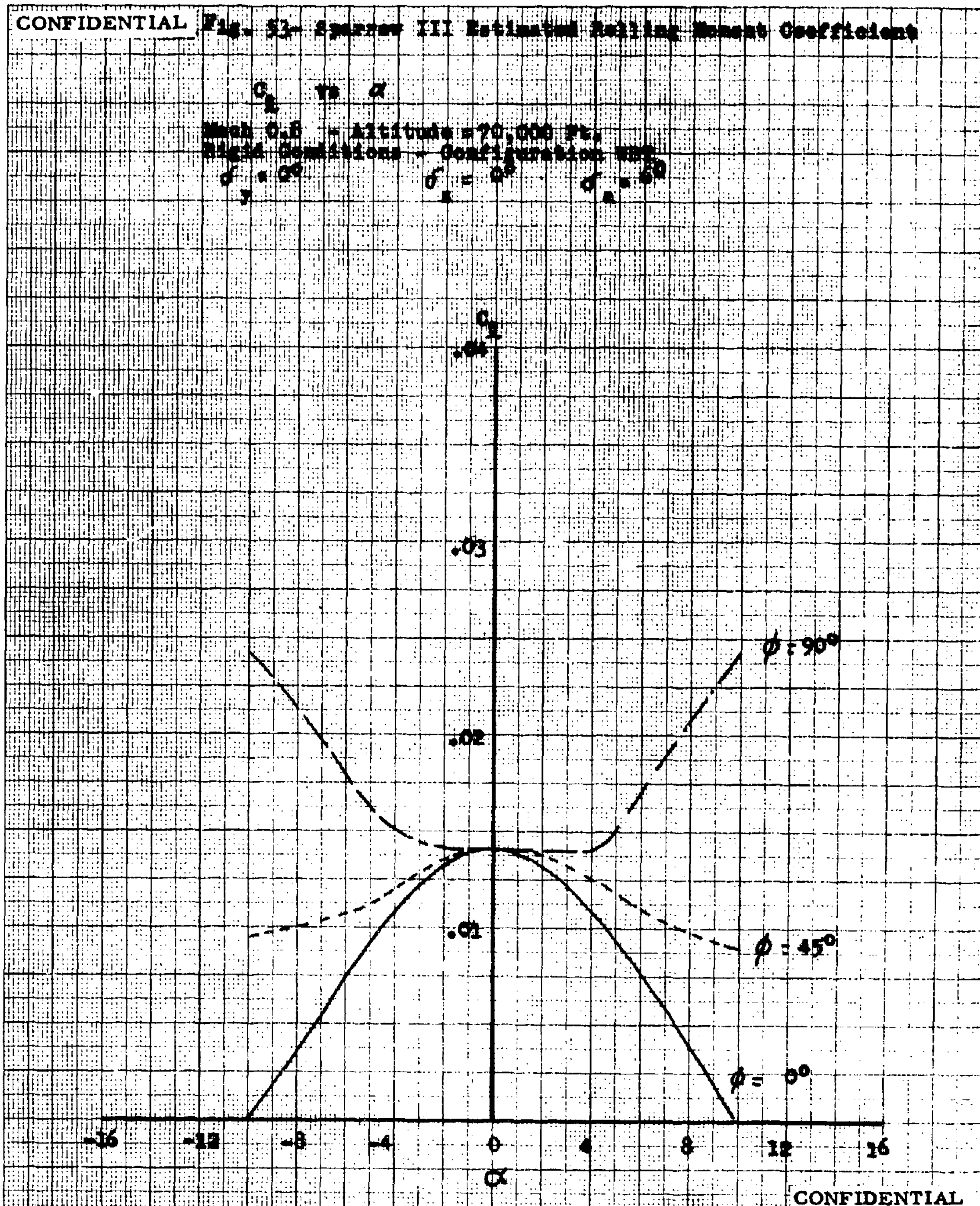
Fig. 53- Sparrow III Estimated Rolling Moment Coefficient
C_l vs α
Mach 0.8 - Altitude = 70,000 Ft.
C_l
.04
.03
.02
.01
$\phi = 90°$
$\phi = 45°$
$\phi = 0°$
-16
-12
-8
-4
0
4
8
12
16
α

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Fig. 54- Sparrow III Estimated Rolling Moment Coefficient

C_l vs α

Mach 0.87 - Altitude - 70,000 Ft.
Rigid Conditions - Configuration WBT
$\delta_y = 0^\circ$ $\delta_z = 0^\circ$ $\delta_a = 0^\circ$

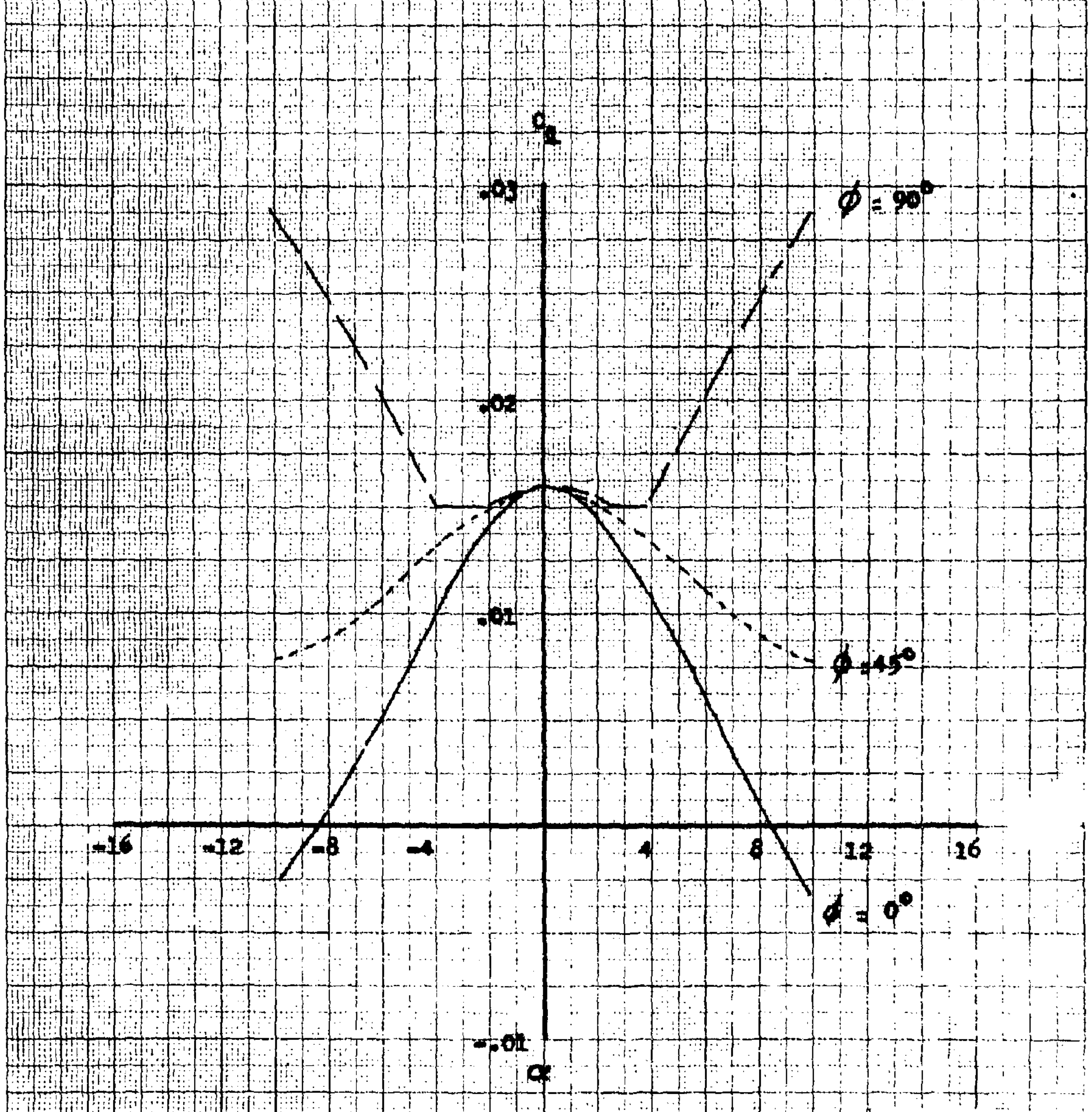

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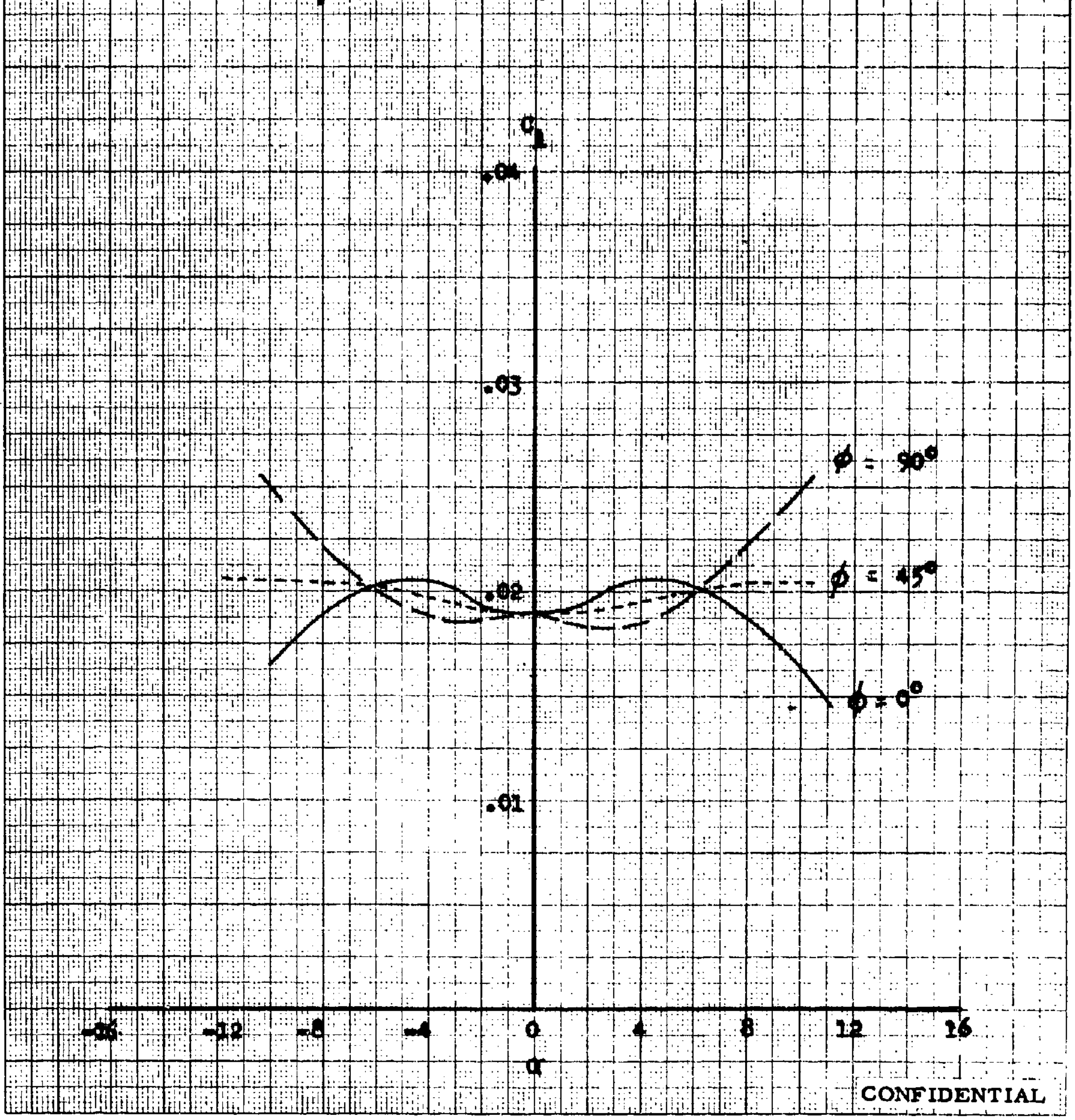
Fig. 55- Sparrow III Estimated Rolling Moment Coefficient

C_l vs α

Mach 1.0 - Altitude = 70,000 Ft.
Rigid Conditions - Configuration WBT
$\delta_y = 0°$ $\delta_z = 0°$ $\delta_x = 6°$



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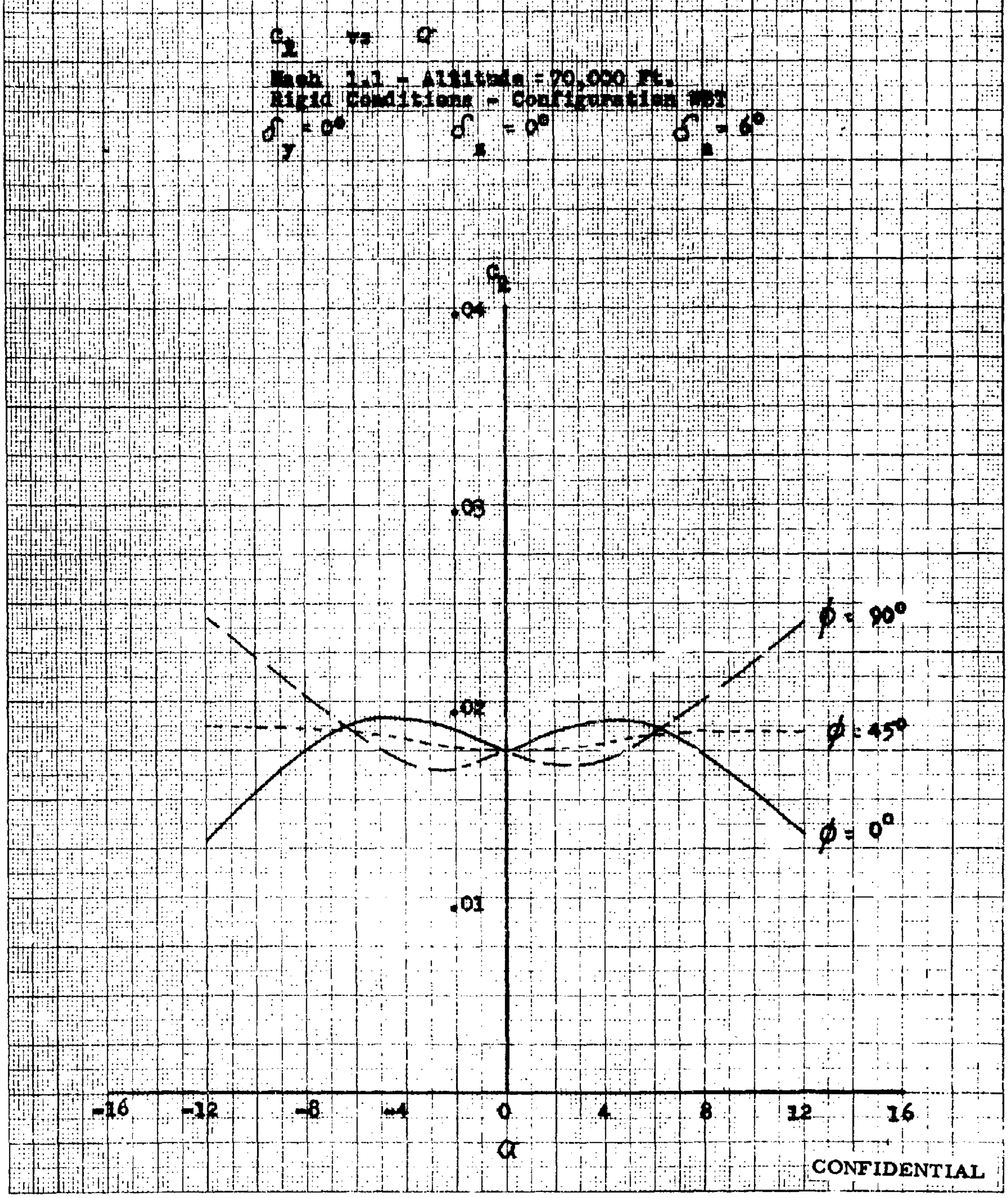

Fig. 56- Sparrow III Estimated Rolling Moment Coefficient

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Fig. 57- Sparrow III Estimated Rolling Moment Coefficient

C_l vs α

Mach 1.3 - Altitude-70,000 Ft.
Rigid Conditions - Configuration WBT

$\delta_y = 0°$ $\delta_z = 0°$ $\delta_a = 6°$

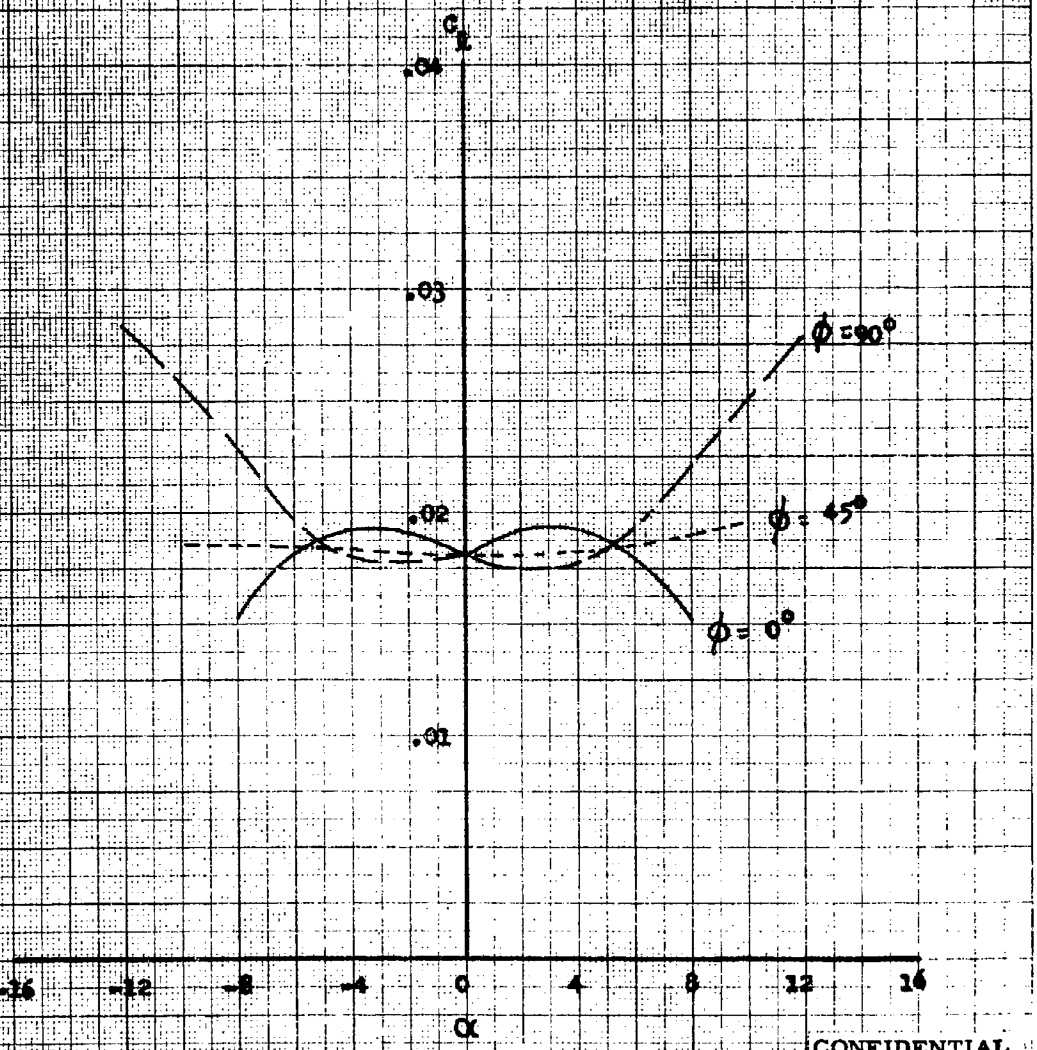

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Fig. 58- Sparrow III Estimated Rolling Moment Coefficient

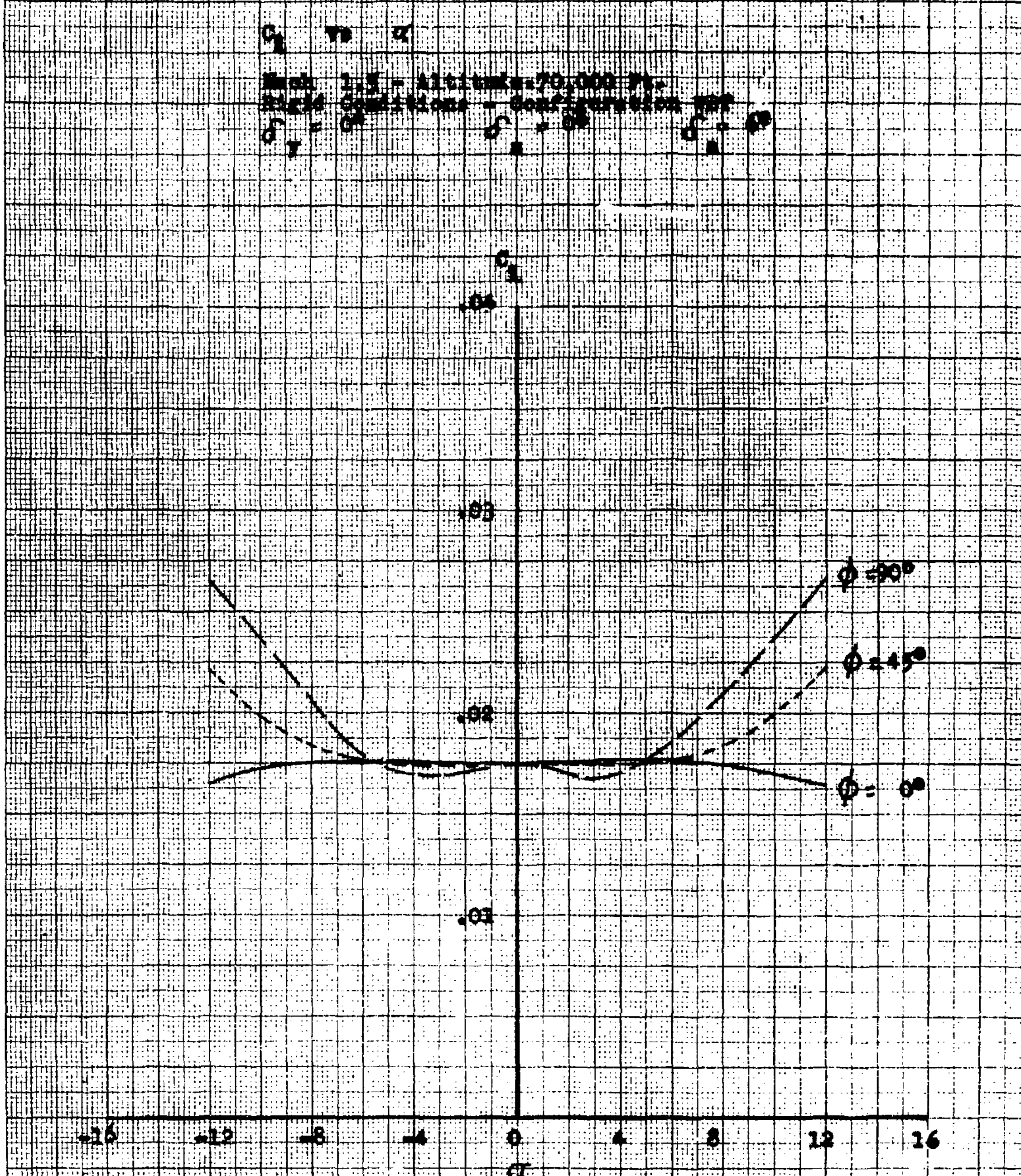

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Fig. 59- Sparrow III Estimated Rolling Moment Coefficient

C_l vs α

Mach 2.0 - Altitude = 70,000 Ft.
Rigid Conditions - Configuration [illegible]

$\delta_y = 0°$ $\delta_z = 0°$ $\delta_n =$ [illegible]

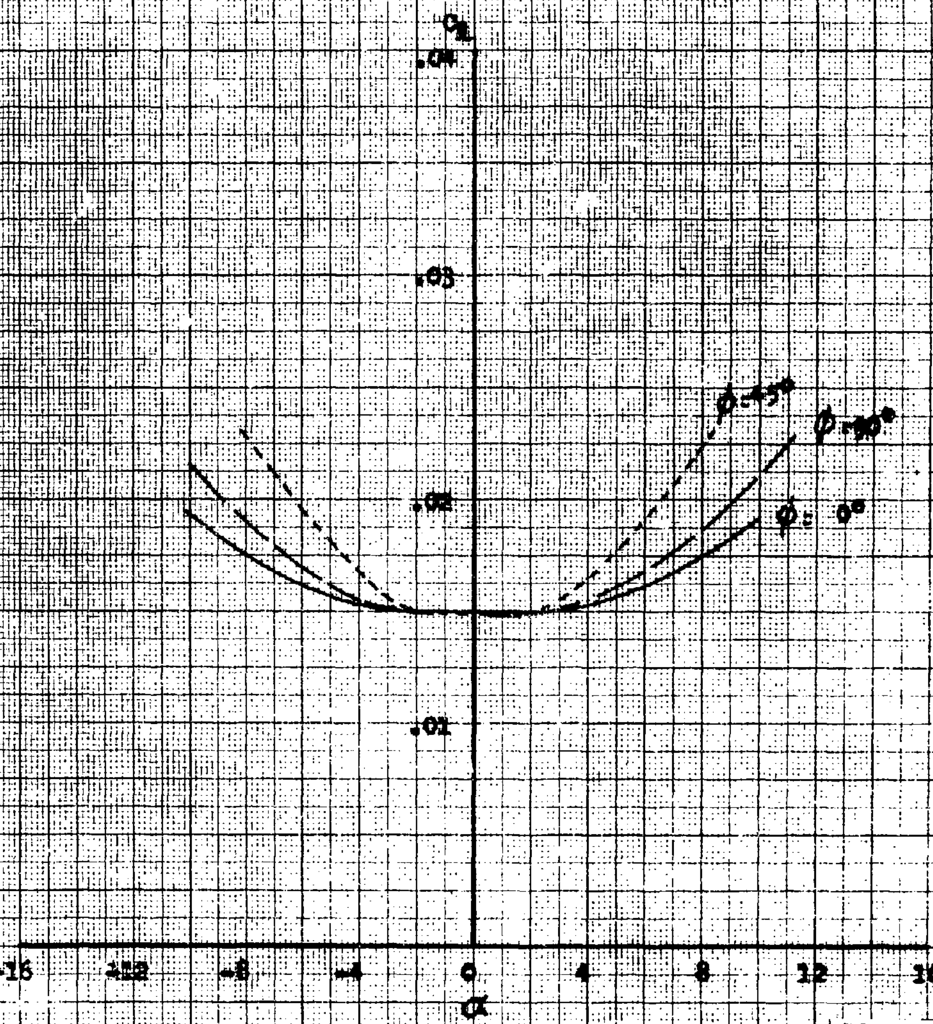

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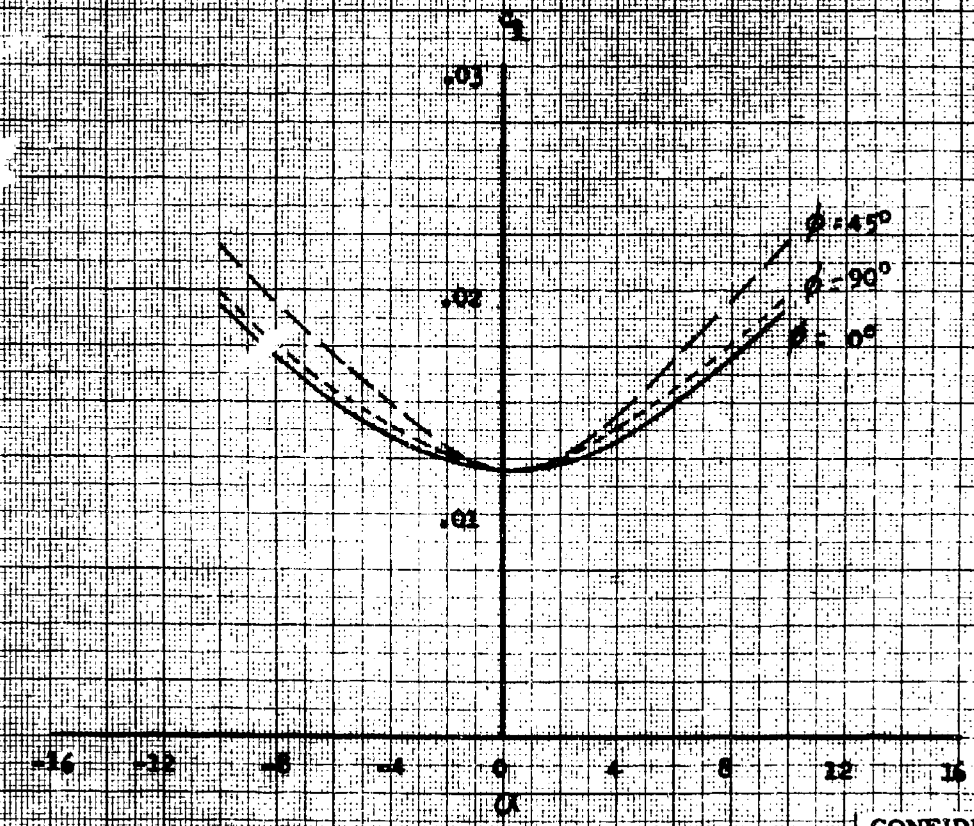
Fig. 60- Sparrow III Estimated Rolling Moment Coefficient

C_l vs α

Mach 2.5 - Altitude - 70,000 Ft.
Rigid Conditions - Configuration BDT

$\delta_y = 0^\circ$ $\delta_z = 0^\circ$ $\delta_a = 6^\circ$



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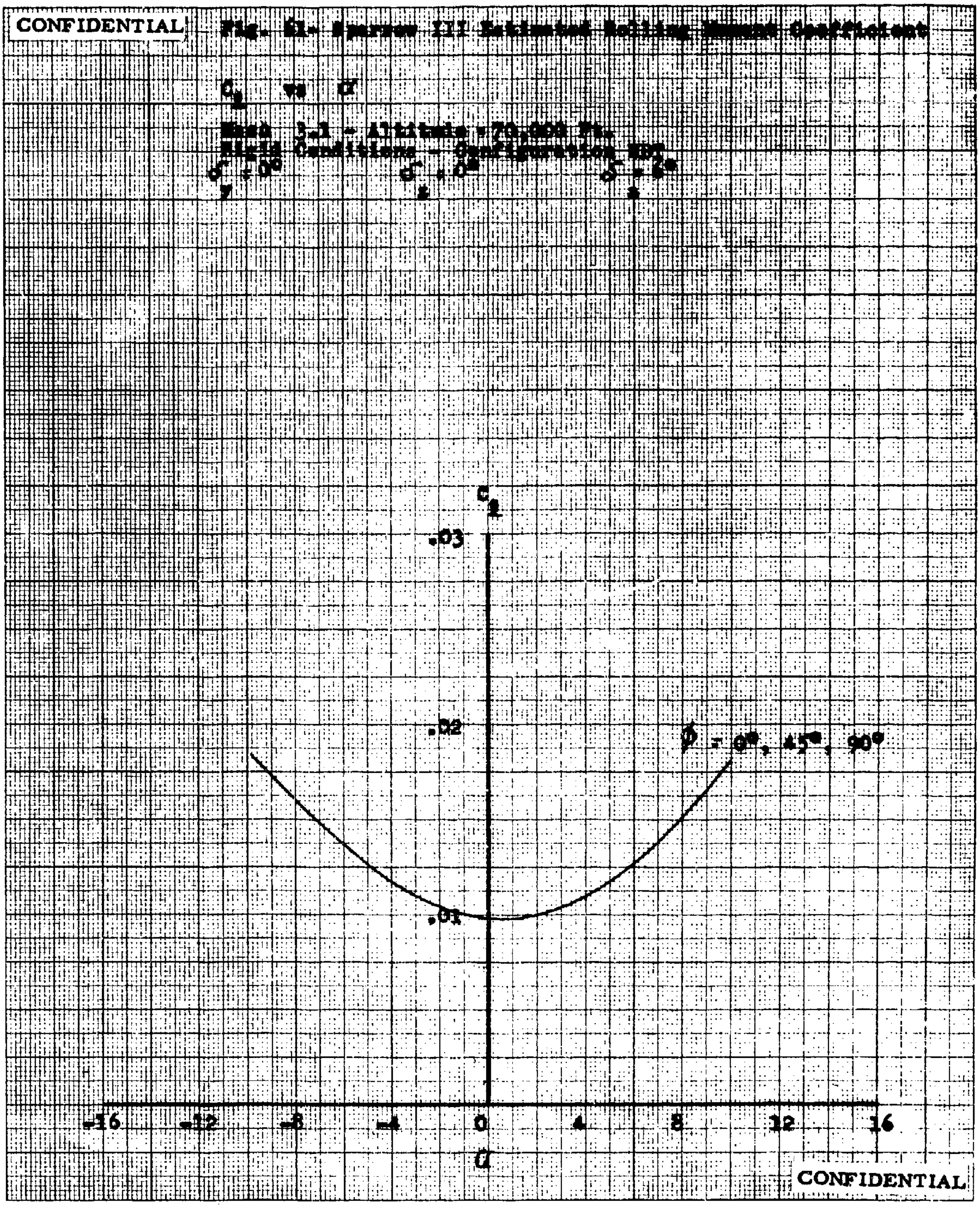
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Fig. 21- Sparrow III Estimated Rolling Moment Coefficient
C_l vs α
C_l
.03
.02
.01
ϕ = 0°, 45°, 90°
-16
-12
-8
-4
0
4
8
12
16
α
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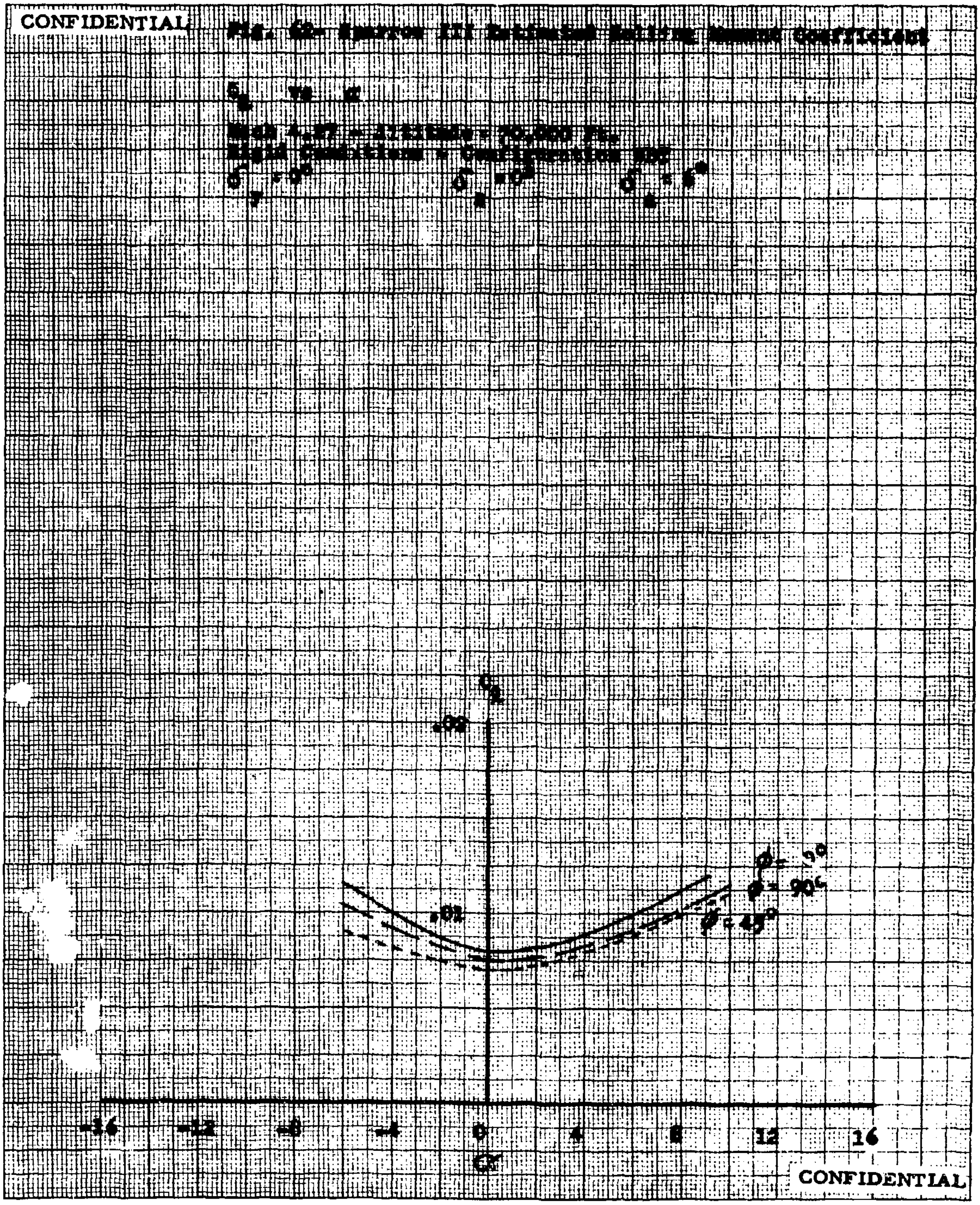
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Fig. 62-
.02
.01
φ = 0°
φ = 90°
φ = 45°
-16
-12
-8
-4
0
4
8
12
16
α
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Fig. 63- Sparrow III Estimated Rolling Moment Coefficient Due to Aileron Deflection

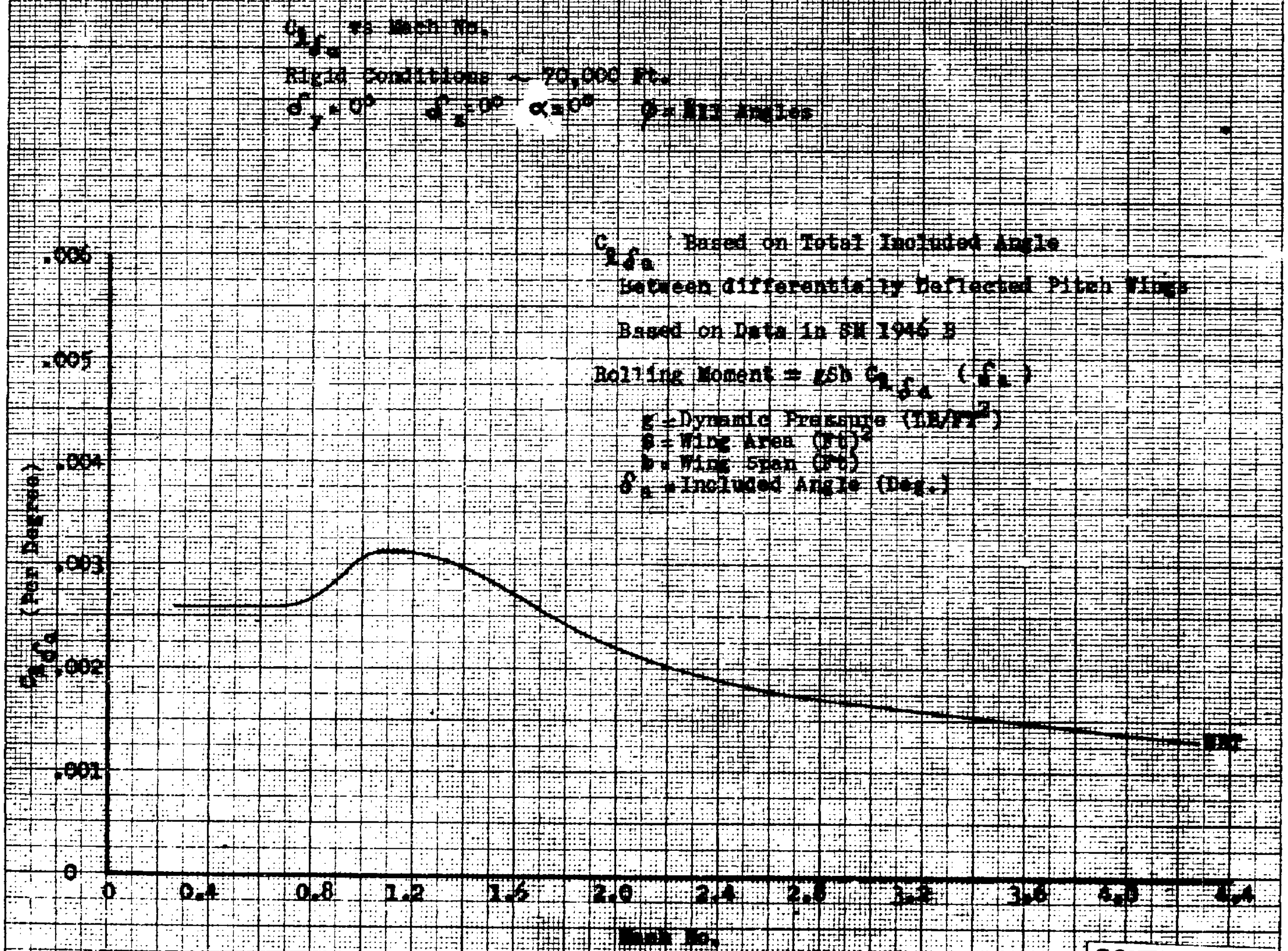

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Fig. 64- Sparrow III Estimated Roll Moment Damping Coefficient

C_{l_p} vs Mach No.

Configuration WBT

$$C_{l_p} = \frac{\partial C_l}{\partial\left(\frac{Pb}{2V}\right)}$$

$$\text{Roll Damping Moment} = \frac{qSb^2}{2V} C_{l_p} \dot{\phi}$$

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Fig. 65- Sparrow III Wing Aeroelastic Correction Factor

Kw vs Mach No.

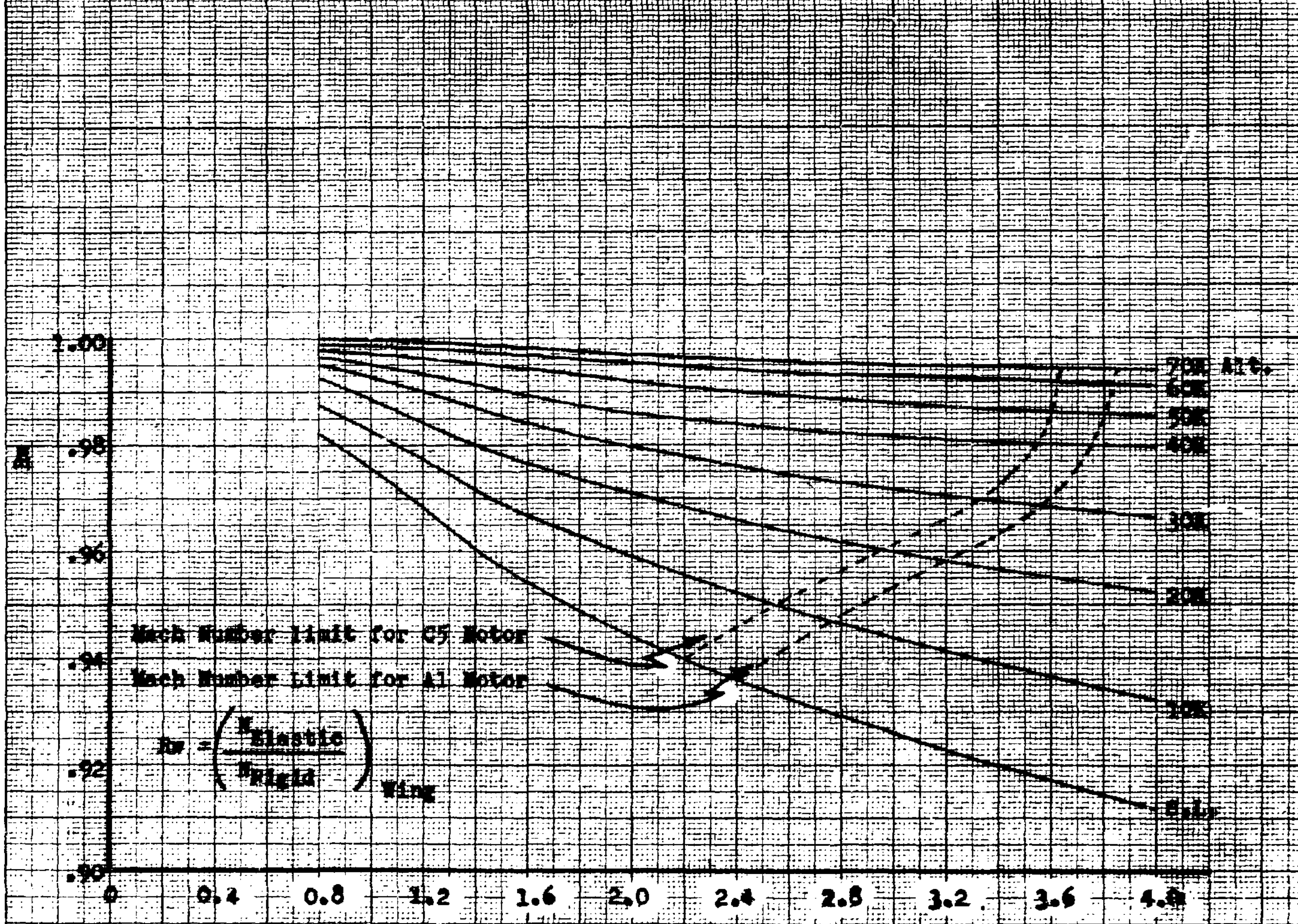

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Fig. 66- Sparrow III Tail Aeroelastic Correction Factor

P_t vs Mach No.

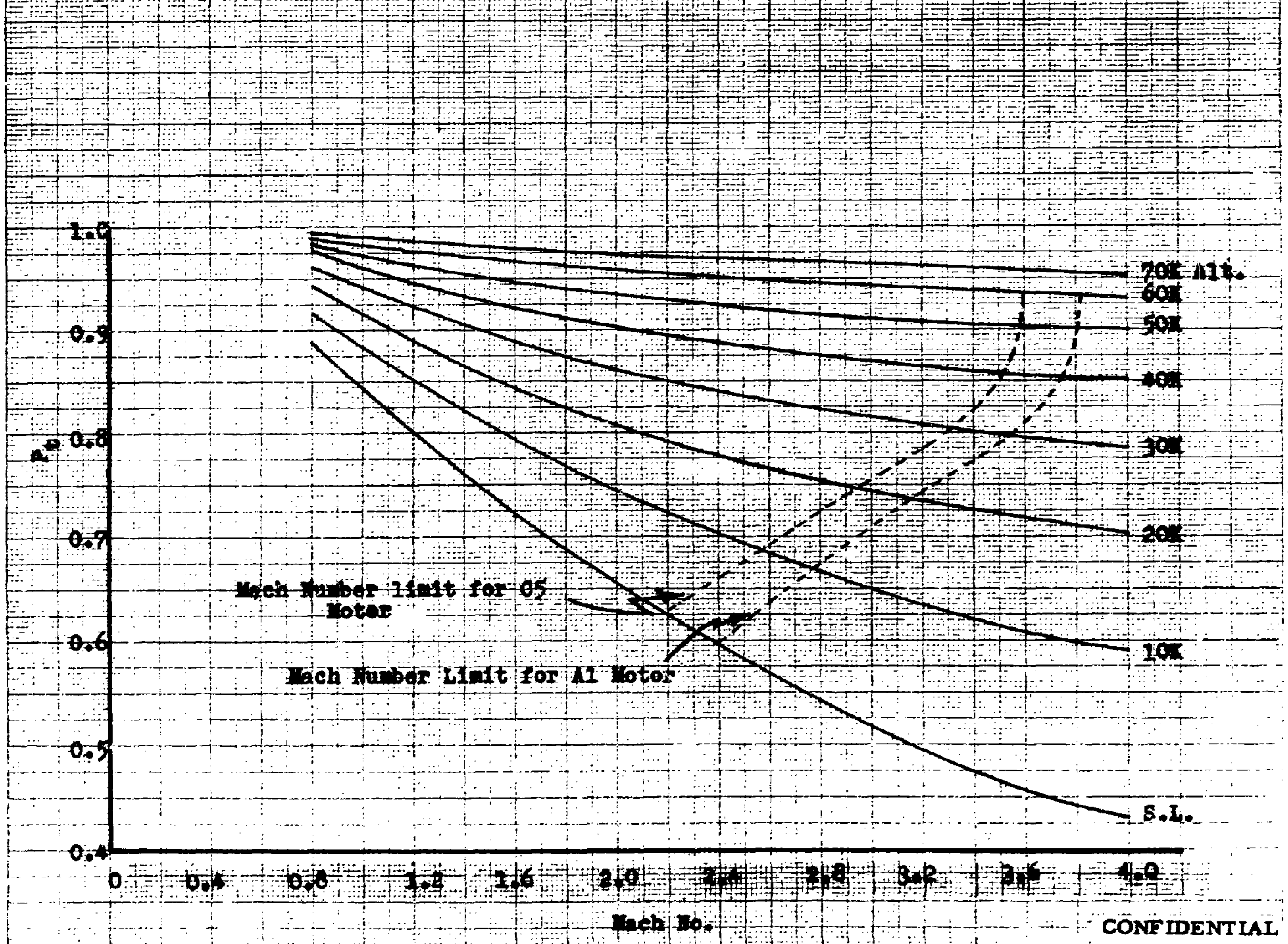

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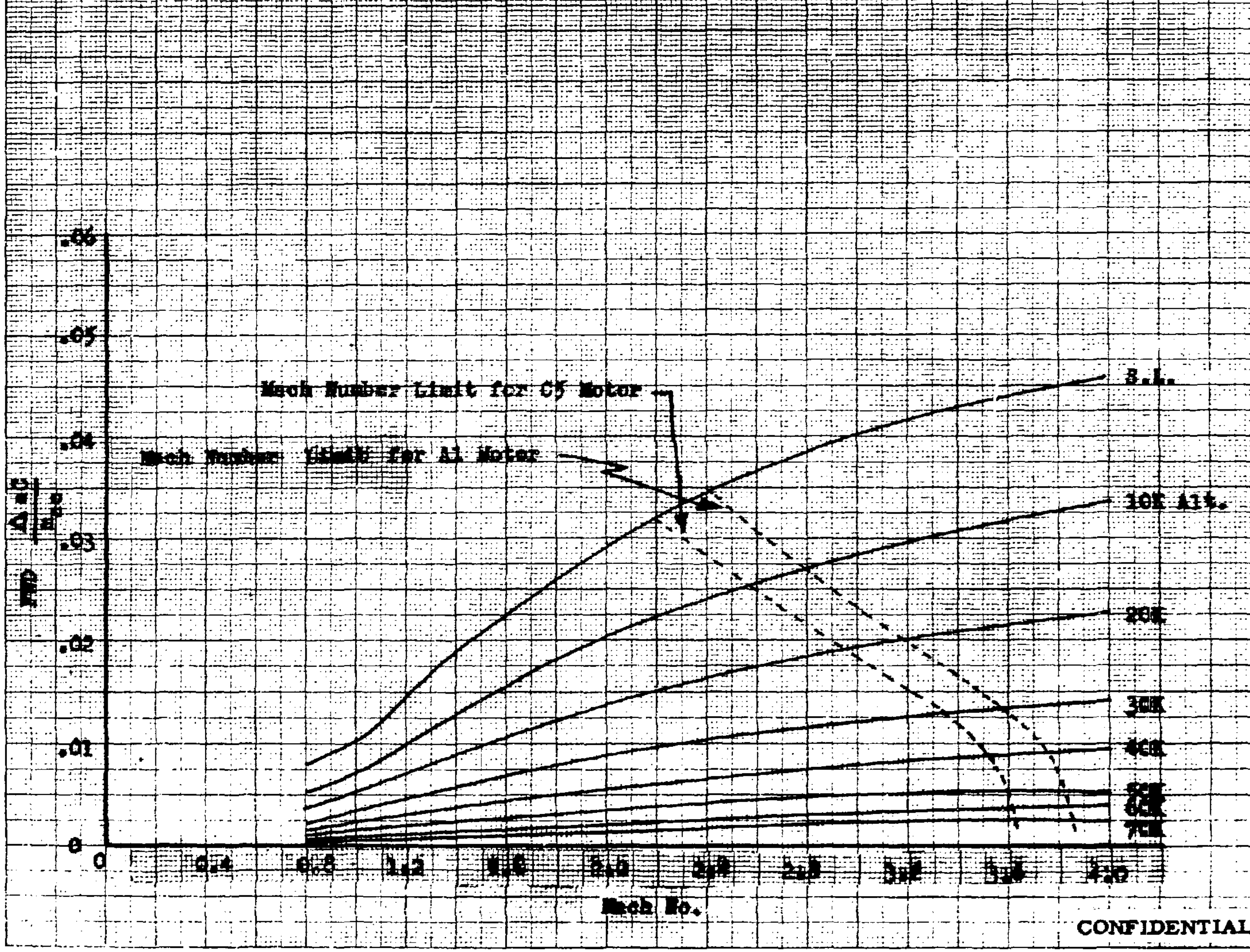
Fig. 67- Sparrow III Aerodynamic Center Aeroelastic Correction Factor

PMD vs Mach No.



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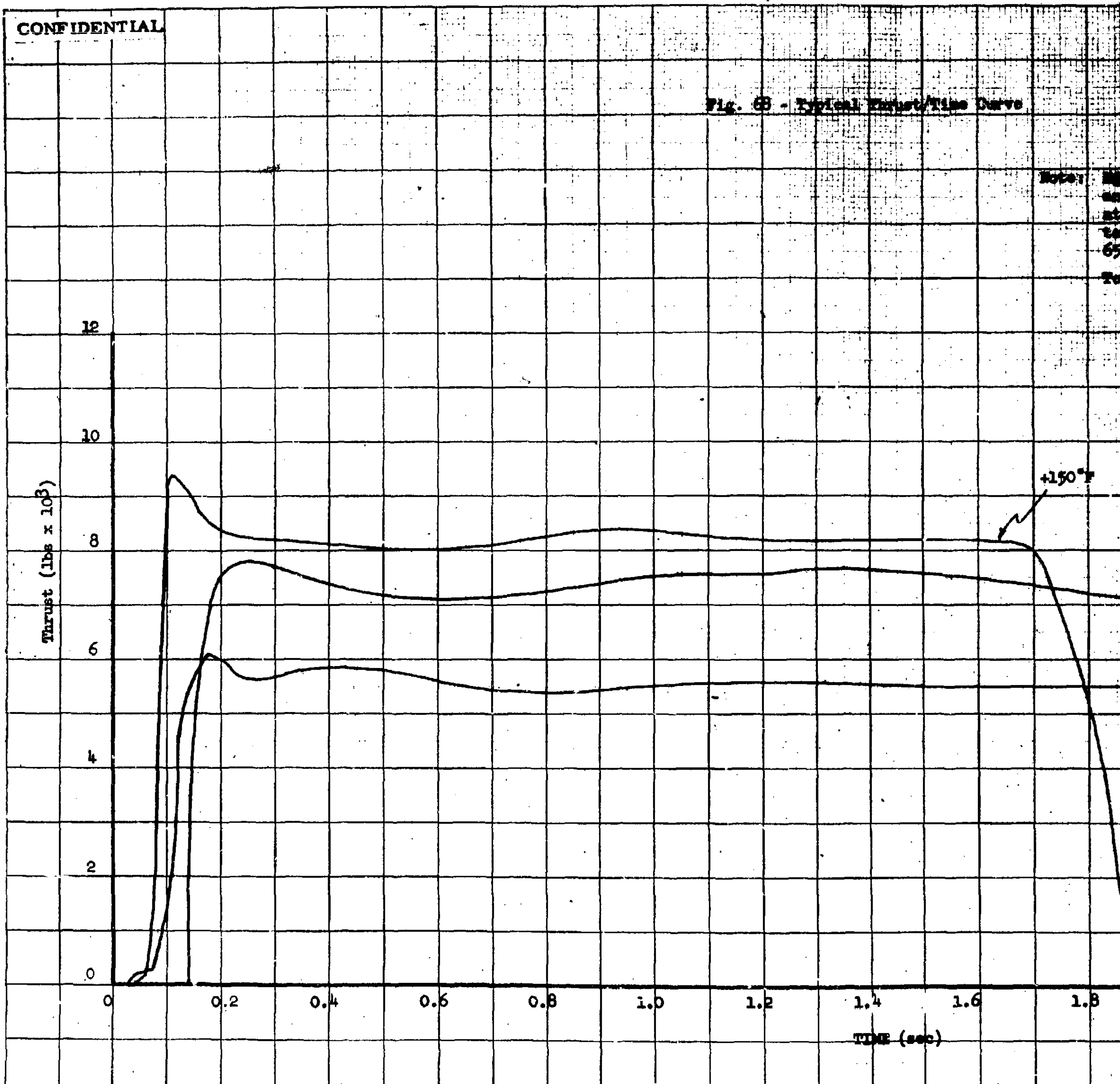
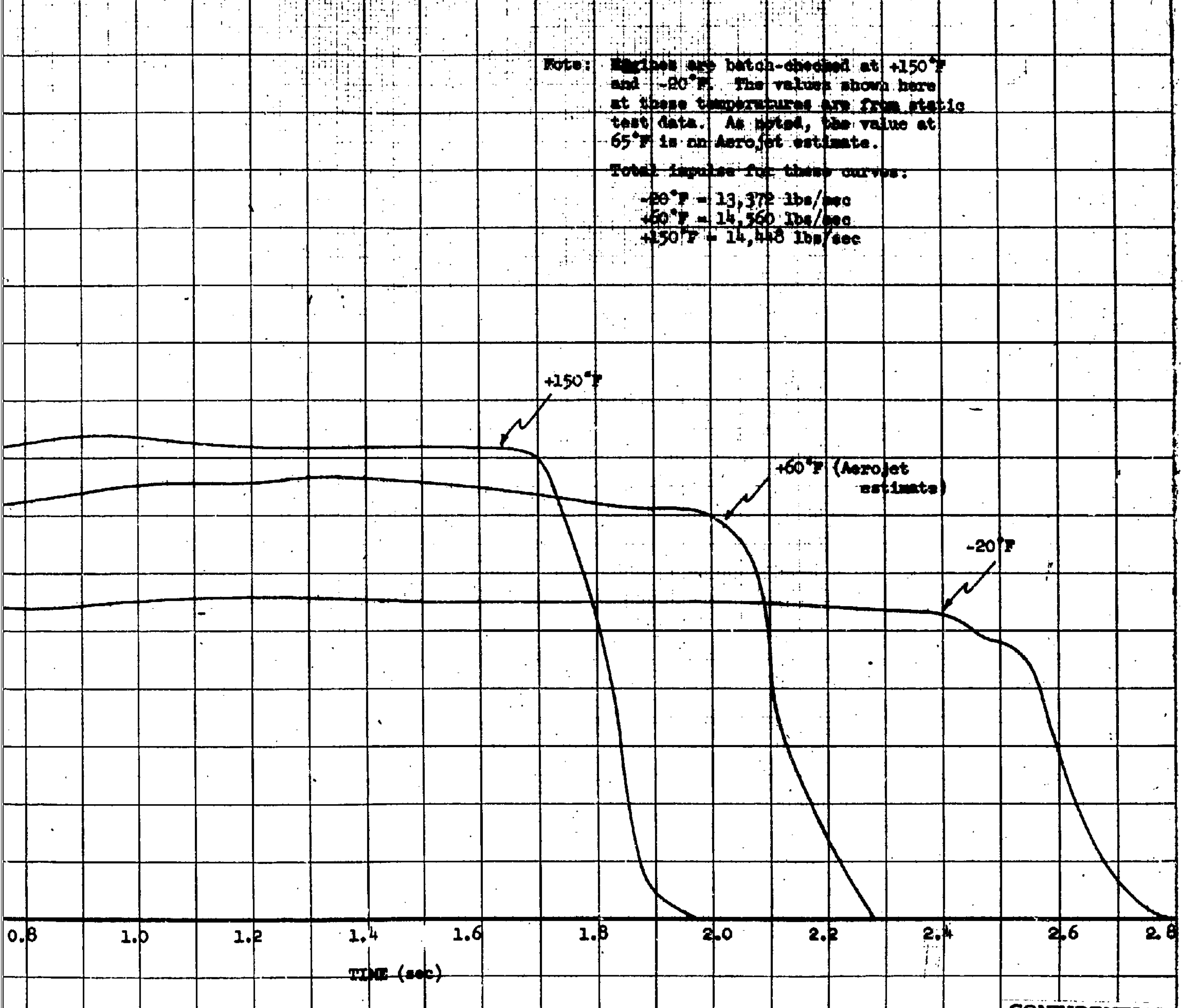


Fig. 6B - Typical Thrust/Time Curve

Fig. 68 - Typical Thrust/Time Curve



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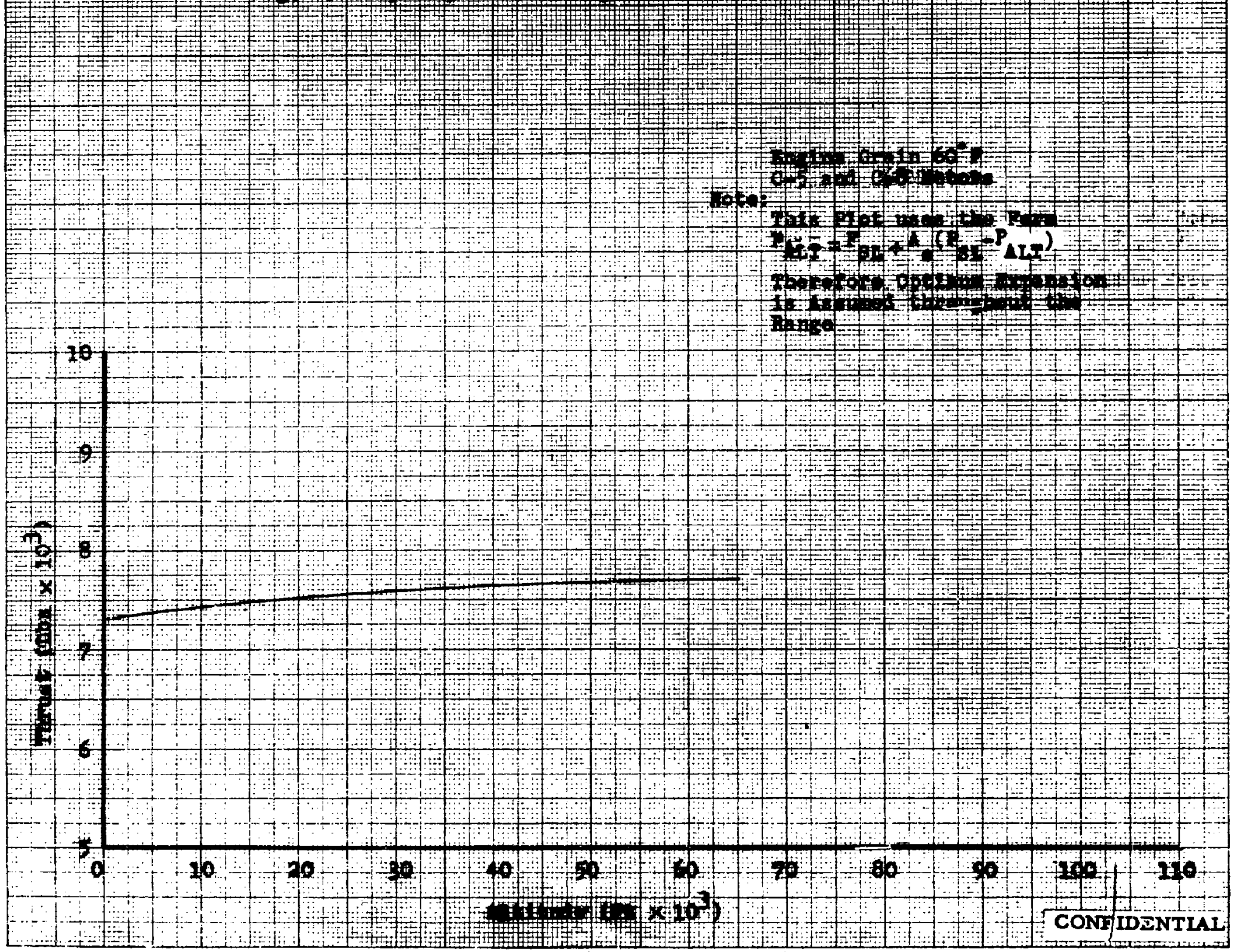

Fig. 69 - Sparrow III - Change of Thrust with Altitude

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